STUDIES OF THE TERRESTRIAL ENVIRONMENT IN THE SUDBURY AREA 1978 - 1987

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IN THE SUDBURY AREA

1978-1987

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NORTHEASTERN REGION

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I. SUMMARY

The terrestrial effects of sulphur dioxide (SO_2) and heavy metals emitted from smelters in the Sudbury area have been monitored by the Ontario Ministry of the Environment since 1970. Over the past two decades through various abatement programs, emissions from the major smelters have been significantly reduced. As a result, less acute SO_2 injury has been observed on vegetation in the Sudbury area. The number of potentially injurious fumigations recorded by Ministry air quality monitors has decreased in recent years.

A total of 650 complaints of injury to vegetation were examined in the period 1970 to 1987, of which approximately 48% were diagnosed as contaminant injury.

Permanent vegetation sample sites were established in the Sudbury area at 21 locations in 1970. Samples of soil, forage and foliage of white birch were collected several times during the growing season each year from 1970 to 1976 and also in 1979 and 1984.

The results of chemical analysis of the soil and vegetation samples indicated that nickel, copper, sulphur and, to a lesser extent, arsenic and selenium concentrations were elevated in the vicinity of the smelters (Sudbury, Garson, Skead). Concentrations decreased with distance from the smelters. Concentrations of copper, nickel, arsenic, lead,

selenium and sulphur have generally decreased in vegetation in recent years. This is consistent with decreases in overall emissions of SO_2, and hence particulates, from Sudbury area smelters since the 1970's.

Soil pH measurements taken in the Sudbury area between 1970-79 did not reveal a distinct trend over time.

The mossbag monitoring network carried out in 1976-77 showed patterns of accumulation which indicated that elevated concentrations of copper, iron, nickel and cobalt were centered at Copper Cliff and Falconbridge and that they decreased with increasing distance from these centres. Iron was accumulated in the greatest quantity of any element tested and over the widest area, and was particularly associated with the Falconbridge source. The highest concentrations of arsenic were also associated with the Falconbridge source.

Large scale land reclamation efforts carried out in the Sudbury area have resulted in the revegetation of some 3,000 ha and visually improved the surrounding countryside. The application of agricultural limestone has reduced the bio-availability of toxic metals and allowed development of vegetation on the treated areas.

II. INTRODUCTION

Emissions, primarily sulphur dioxide and heavy metals, from the Sudbury area smelters of Inco Ltd. and Falconbridge Ltd. have been responsible for a considerable amount of injury to vegetation in the Sudbury region. This injury and alteration of the forest environment have been investigated and documented by a number of agencies and researchers (4, 5, 7, 8, 9, 10, 11, 12, 13, 26).

The Ministry of the Environment has continuously monitored sulphur dioxide emissions from the Sudbury smelters at numerous locations since 1953. Over the years, several modifications were made to the network with several stations added or deleted. Previous Ministry reports (15, 21, 22) demonstrated an improvement in air quality since 1972 by the monitoring network and this correlated with a reduction in observed vegetation injury.

In 1970, the Phytotoxicology Section of the former Air Management Branch began sampling vegetation and soil in the Sudbury area at a number of locations for chemical analysis. Air Quality Assessment staff (Pesticides and Terrestrial Effects Unit) of the Northeastern Region have continued this program. Over the years, this program has been modified following examination of each year's data.

Basically, two vegetation and soil sampling studies evolved over the years. One involved a routine surveillance study that was consisted of vegetation complaint investigations, visual terrestrial effects surveys and a periodic terrestrial sampling of 19 Sudbury vicinity locations and 2 control locations. As part of this study air quality data were correlated with vegetative injury and the number of potentially injurious fumigations from industrial emissions were calculated. The other study involved an intensive terrestrial sampling program where over 90 Sudbury vicinity locations are sampled every five years in an effort to produce concentration maps for elements associated with the Sudbury Smelter Complex.

This report deals with data compiled as part of the routine surveillance study for the time period between 1970 and 1987 with emphasis on data collected post 1978. The information gathered in the intensive terrestrial sampling study will be published in a separate report.

III. "UPPER LIMITS OF NORMAL" CONTAMINANT GUIDELINES

The Ontario Ministry of the Environment has conducted numerous vegetation and soil sampling programs throughout the Province of Ontario. Based on experience with these programs, as well as on data published in the literature, a set of guidelines has been developed to indicate the concentrations of individual chemical elements which are considered to be above background concentration limits. Reference is made to these guidelines throughout this report.

The upper limits of normal contaminant guidelines essentially represent the expected maximum concentrations of contaminants in surface soil (non-agricultural), foliage (deciduous and current year coniferous trees and shrubs) and grass from areas of Ontario not subject to the influence of point sources of emissions.

The guidelines were calculated by taking the arithmetic mean of available analytical data and adding three standard deviations of the mean.

Values presented do not necessarily mean that there is toxicity involved, but that there is evidence of contamination above average normal levels. The concentration limits of contaminants in vegetation or soil is considered to be a tool for use by phytotoxicology investigators in

interpreting the results of chemical analyses. Certain limitations exist with these established levels, and investigators must judge their use in supplementing other results and observation from field assessment surveys. The following table lists the upper limit of normal concentration used in this report.

Element	Vegetation	Forage	Soil
Arsenic	2	8	10
Magnesium	0.7%	-	1%
Cobalt	3	8	25
Copper	20	20	60
Iron	500	500	3.5%
Lead	30	20	150
Calcium	3%	-	3%
Nickel	30	25	60
Selenium	0.5	0.5	2
Sulphur	0.4%	0.5%	0.1%

Values are reported in ug/g; except magnesium, calcium, sulphur and iron (soil) are shown as percent dried weight.

Values for calcium and magnesium in forage were not established due to insufficient sample size.

IV. SULPHUR DIOXIDE MONITORING

Many changes have taken place since the network of sulphur dioxide monitors was established in the Sudbury area in 1953. In keeping with technological advancements, the network was upgraded with newer, more accurate and efficient monitors that required less maintenance. The original Thomas Autometers were replaced in turn by Davis conductimetric and Beckman 906 coulometric instruments. These in turn have been replaced by pulsed fluorescent type monitors such as Thermo Electron Series 43 and more recently by Monitor Labs Model 8850.

In 1978, the network consisted of 17 stations as indicated in Table 1 (Locations are mapped on Figure 9). After review of the large historical SO_2 data base, several alterations were made to the network. In October of 1979, the Grassy Lake station was discontinued. During 1980, the Verner, Penage and Morgan stations were terminated. In June of 1981, the Lockerby and Chiniguchi Lake stations were also discontinued. New stations were established on Long Lake Road, Laurentian Hospital and Happy Valley in 1981. The latter station was closed down in November of 1982. A new station was set up in Mikkola (Walden) in May of 1982. The Laurentian Hospital station was moved to Science North in July 1984. Other monitoring stations discontinued were St. Charles (January

1984), Burwash and Callum (February 1986) and Temagami (June 1986). A SO_2 monitoring station was established in Copper Cliff in October 1987. The current network of 11 stations is equipped either with TECO Series 43 SO_2 monitors or with Monitor Labs 8850 fluorescent SO_2 analysers. All stations have now been winterized and are operated on a year-round basis, which contrasts with the earlier network for which most of the monitoring was done only during the growing season (May to October). The network of monitors is now electronically connected (with the exception of the Lake Temagami station) to the Ministry office in Sudbury. The SO_2 data are telemetered from each station to a central data collection unit in Sudbury. Five-minute average readings are relayed to the central system and hourly averages are stored and printed at the terminal.

A summary of the SO_2 monitoring data collected during the period from May to October for the years 1978 through 1987 are represented in Tables 1-10. A complete analysis of the data will be published in a separate report. The Ontario criterion (0.25 ppm for 1 hour) was equalled or exceeded on 150 occasions in 1978, 113 in 1979, 158 in 1980, 199 in 1981, 45 in 1982, 141 in 1983, 122 in 1984, 161 in 1985, 106 in 1986 and 146 in 1987. The lower totals in 1979 (113) and 1982 (45) reflect major shutdown years for INCO and Falconbridge.

V. SULPHUR DIOXIDE ABATEMENT PROGRAM

Beginning in 1972, both Inco Ltd. and Falconbridge Ltd. instituted significant measures to reduce ground level concentrations of SO_2 through reduced emissions and more effective atmospheric dispersion. The measures which were used included:

1. The closing of the Inco Ltd. smelter at Coniston and the pyrrhotite plant at Falconbridge prior to the 1972 growing season.

2. Limiting SO_2 emissions from the Inco Ltd. Iron Ore Recovery Plant to 227 tonnes/day in April, 1972.

3. The commissioning of the 381 m stack at the Inco Ltd. Copper Cliff Smelter in August, 1972.

4. Limiting SO_2 emissions from Falconbridge Ltd. (a 1973 Control Order) to 422 tonnes/day by May, 1979.

5. Limiting of SO_2 emissions from the Copper Cliff Smelter to 3,265 tonnes/day (Control Order July, 1978).

6. A regulation was made under the Environmental Protection Act (EPA) in September 1980, limiting SO_2 emissions from Copper Cliff Smelter to less than 2,268 tonnes/working day up to December 31, 1982, and 1770 tonnes/working day after this date.

7. In 1978, Falconbridge Ltd. commissioned a new smelting process (fluid bed roasting and electric furnace smelting) with sulphur fixation as sulphuric acid. This resulted in more efficient separation and rejection of pyrrhotite.

8. Inco Ltd. shut down operation during July of 1981 and slowed production down in July of 1984.

9. Falconbridge Ltd. ceased operation during July and August of 1978 and July of 1981 and 1984. There was also a shutdown of operations during the period June 27, 1982 to January 2, 1983.

10. A regulation under the EPA was passed in December 1985 which further reduced the Inco's Sudbury Smelter operations SO_2 to 685 kt/yr.

Operational changes also resulted in a decrease of emitted annual SO_2 tonnage from both Inco Ltd. and Falconbridge Ltd., as a result of strikes as shown in Table 23. The 1969 emissions were reduced due to extensive labour strikes experienced by both companies. A major strike occurred from September 1978 to June 1979, during which all Inco Ltd. operations were halted. An Inco strike also occurred during the month of June 1982, and due to a depressed word nickel market, Inco closed down operations on June 30, 1982 until April 1, 1983.

VI. POTENTIALLY INJURIOUS SO_2 FUMIGATIONS

The Sudbury area has had a history of typical acute sulphur dioxide injury to vegetation during the growing season (May to October). Initially, most of the Sudbury monitors were established at locations where vegetation injury by SO_2 was most frequent and most severe. The establishment of these monitors made it possible to relate the appearance of vegetation injury to fumigations of varying duration and SO_2 concentrations.

From some of the first attempts to relate vegetation injury to SO_2 fumigations under controlled environmental conditions, Tebbins and Hutchinson (24) derived the following equation:

$$t = \frac{0.8}{C - 0.2}$$

where t = time required to cause injury and C = concentration of SO_2 in ppm.

This suggests that injury could occur under the following conditions:

1.0 ppm SO_2 for 1 hour
0.6 ppm SO_2 for 2 hours
0.4 ppm SO_2 for 4 hours
0.3 ppm SO_2 for 8 hours

The limitations of this relationship include 1.5 ppm SO_2 as a maximum concentration and assumption that a constant 0.2 ppm SO_2 will not cause acute injury. It also assumes that no injury will result from fumigations during periods of darkness since the foliage stomata will be closed in dark periods and therefore SO_2 will be prevented from entering the leaf.

In 1963, Dreisinger (7, 8) attempted to relate the applicability of the Tebbins and Hutchinson (24) equation to the Sudbury field situation. It was found that injury could occur under the following conditions:

0.95 ppm SO_2 for 1 hour
0.55 ppm SO_2 for 2 hours
0.35 ppm SO_2 for 4 hours
0.25 ppm SO_2 for 8 hours

If any of these conditions were met in the daylight hours, then the fumigation intensity was assigned a value of 100 for convenience. If the fumigation intensity value was 100 or over, then the fumigation was termed a potentially injurious fumigation (PIF). A PIF does not always result in injury since other factors such as species sensitivity, growing season and environmental factors also have some bearing on susceptibility to injury.

A summary of the dates, frequency and intensity of PIFs recorded at each monitoring station from 1978 to 1987 is included in Tables 11-20. Similar information for the years prior to 1978 has been included in earlier reports (18, 19). The yearly maximum fumigation intensities at each monitoring location from 1970 to 1987 are presented in Table 21. The highest values recorded over the past seven years (1978-1987) occurred at Long Lake Road, Skead and Happy Valley. During this time period, potentially injurious fumigations were recorded in one or more years at New Sudbury, Coniston, Falconbridge Road, Skead, Hanmer, Long Lake Road, Mikkola, Rayside and Happy Valley.

A summary of the frequency of PIFs recorded at monitors is provided in Table 22. It is evident from these data that fumigations occurred most frequently at Skead, Garson and to a lesser extent at Rayside and Ash Street. The 217 PIFs recorded at these stations represented approximately 70% of all the PIFs measured in the Sudbury area. Only 46 PIFs were recorded over the past 10 years (1978-87) and 10 of these occurred at the Happy Valley monitor which was operating between 1981-1982. Also, about 60% of the PIFs in the table occurred in the period 1970 to 1972 indicating a significant improvement in air quality after 1972.

VII. COMPLAINTS OF VEGETATION INJURY BY AIR POLLUTANTS

Over the past eighteen years (1970-87), the number of complaints of possible air pollution damage to vegetation in the Sudbury area has varied considerably from as low as 12 in 1977 to a high of 118 in 1981. These complaints were received, investigated and reported on by personnel of the Ministry of the Environment.

The number of complaint notifications of air contaminant injury to vegetation received during the past 18 years are shown in the table below, together with the number diagnosed as exhibiting contaminant injury.

Year	Number of Complaints Received	Number of Complaints Diagnosed As		
		SO_2 Injury	Other Contaminant	Non-Contaminant
1970	16	9	-	7
1971	14	10	-	4
1972	27	15	-	12
1973	65	15	-	50
1974	46	20	1	25
1975	31	6	8	17
1976	30	6	3	21
1977	12	2	3	7
1978	32	2	20	10
1979	50	1	22	27
1980	17	0	1	16
1981	118	1	85	32
1982	30	0	5	25
1983	35	1	7	27
1984	36	4	11	21
1985	17	0	5	12
1986	14	2	2	10
1987	61	5	39	16
TOTAL	650	99	212	339
% of Total	100	15	33	52

The high number of complaints in 1981 was a direct result of fallout from the Copper Cliff Smelter during shutdown or start-up operations. This fallout, made up of primarily nickel, copper and iron sulphate, caused a black spotting symptom on vegetation. Eighty-one of the 118 complaints were black-spot related. A more detailed description of the black spotting problem is provided later in this report.

Complaints resulting from SO_2 injury to vegetation have decreased significantly since 1974. However, four SO_2 related complaints were investigated in the summer of 1984. Three of these complaints originated from potato farmers at Rayside whose crops were injured (17) while the fourth SO_2 complaint came from the Copper Cliff area. In 1987, a total of five SO_2 related complaints were investigated in the Sudbury area primarily due to August fumigations from the Inco Smelter's tall stack.

In 1987, a high number of complaints were investigated which were related to an SO_3 spill from the Inco Acid Plant.

The majority of the complaints involved injury to vegetation caused by insects, pathological agents, physiological stresses and poor cultural practices. Samples collected during complaint investigations formed the bulk of the samples submitted for pathological examination.

VIII. VEGETATION INJURY OBSERVED BETWEEN 1978-1987

a) Injury Caused by Sulphur Dioxide

Ministry of the Environment surveys to evaluate sulphur injury to vegetation in the Sudbury area pre 1978 have been described in previous reports (15, 18, 19). Detailed surveillance programs were conducted during the growing seasons of 1979 and 1981. On August 20, 1979, light to moderate intercostal necrosis (typical SO_2 symptom) was noted on several red oak, white birch and large-toothed aspen on a 100 ha area approximately 2 km to the northeast of the Sudbury airport. This section of land was reserved by the Ministry of Natural Resources for research purposes. A complaint investigation in June, 1981 revealed light SO_2 injury on a 5 acre barley field east of Hanmer. Limited surveillance programs during 1978, 1980, 1982 and 1985 revealed no SO_2 injury to vegetation.

In early August 1984, several potato crops in Rayside showed varying degrees of SO_2 injury (17). The symptoms appeared as typical acute SO_2 injury to the middle-aged foliage. The average area of injury on the affected leaves was approximately 25% of the individual leaf area. By including all leaves (including uninjured, lower leaves), the overall injury to the plants was about 5%. The impact of this injury on crop yield could not be determined. The late planted Superior potato foliage exhibited the most injury, up to 50% in some leaves. The Kennebec variety showed nil to very light injury.

Other affected plant species included smartweed, pin cherry, white birch, oats and red clover. It was estimated that over 450 hectares of vegetation was affected in the Rayside area that year.

An examination of the available air quality data at Rayside in combination with other meteorological data indicate that SO_2 fumigations which could account for the injury, occurred on the afternoon of August 2, 1984. The available information suggest that the Inco smelter complex at Copper Cliff was the source of the SO_2.

Two minor episodes of SO_2 injury to vegetation were investigated in 1986. On May 16 in Copper Cliff, trace SO_2 injury was found on one willow tree. This injury was attributed to fugitive gas at ground level from the Inco smelter. The other occurred in Capreol where a few shrubs (chokecherry, Amur maple and Chinese lilac) and a white spruce were affected. Monitoring data suggested that a fumigation from the Falconbridge smelter on July 16 caused the injury. These plants were introduced from Southern Ontario and are believed to be more sensitive than the indigenous plant species.

In 1987, there were five complaints investigated within the Regional Municipality of Sudbury with confirmed SO_2 injury to vegetation. Four of these complaints were residential in nature and light intercostal necrosis was found on shrubs or garden vegetables. The other complaint was based on light damage to 50 ha of potato crops in Chelmsford. All five incidents were attributed to SO_2 fumigation from Inco recorded on monitors on August 12 and 27.

b) Injury Caused by Other Agents

A total of 468 vegetation samples from the Sudbury area were submitted for pathological examination between 1978 and 1987. The majority of samples were collected in the course of complaint investigations. Only limited numbers of the samples were diagnosed as having been lightly injured by SO_2. In the majority of samples, injury symptoms were caused by a number of other agents as indicated in the table below. More than one agent could be involved in single samples.

Causal Agent	78	79	80	81	82	83	84	85	86	87	Total
SO_2	0	0	0	1	0	1	4	0	5	12	23
Physiological	6	1	0	0	0	4	3	2	14	21	51
Deficiency	0	0	1	0	0	0	1	0	0	0	2
Insect	4	13	8	7	8	5	5	4	5	7	66
Mite	3	1	0	2	0	1	1	0	0	6	14
Fungus	6	24	16	36	5	3	6	24	8	8	136
Bacteria	0	2	0	2	0	1	0	1	0	0	6
Virus	2	0	1	11	1	2	0	1	0	0	18
Other	1	22	25	31	10	1	1	6	1	54	152
TOTAL SAMPLES EXAMINED	22	63	51	90	24	18	21	38	33	108	468

i) "Black Spot" Injury

In the mid-1970s, it was noted that several complaints were received which involved an unknown contaminant which produced a black spotting type of injury to foliage of many plant species. Subsequent episodes in later years made it possible to identify the cause of the problem.

In late 1975, eight complaints of injury to garden plants were investigated by the Ministry of the Environment. As part of the investigation, the extent of the problem was delineated. An estimate of zones of injury to vegetation in the Sudbury area is shown in Figure 1.

In late August and early September 1978, complaints of vegetation injury were again received and investigated. Four distinct incidents within that time period were identified (1). The affected area was very similar to that which was affected in 1975 but also included portions of Copper Cliff.

In September 1978, a similar incident in Falconbridge was investigated and extent of injury delineated (Figure 2).

The black spotting type of injury was again recorded in 1981 and resulted in 81 complaints to the Ministry of the Environment. Two distinct episodes were encountered with one occurring in July while the second took place in August. The July incident affected the same general area as in 1975, but most of the injury in August was observed in Copper Cliff. The total area affected by both occurrences is given in Figure 3.

The symptoms were present on most broadleaf species which had exposed leaves. Protected leaves and narrow-leaved species were not injured. Injury was not observed on some species, such as honeysuckle (Lonicera spp.). The symptoms usually appeared as discrete circular black spots about 0.5-1.0 cm in diameter. On some species, more distinctive symptoms developed. Large red anthocyanotic rings developed on Impatiens foliage surrounding a bleached tan band around the black centre. In other species, such as raspberry, the anthocyanotic ring was narrow and therefore less pronounced. With aging and drying, the black central portion usually became surrounded by a bleached tan to brown band, and frequently the central portion cracked and broke away. The margins of the necrotic lesions were usually sharply defined.

Under the microscope, the lesions were typically bifacial. On the upper surface within the black central portion, a residue was present. The material was amorphous and appeared to be a residue left after evaporation of a liquid deposit.

No pathogenic organisms could be isolated from the black spots.

The severity of the problem at any location could be related directly to the number of black spots present. In the most heavily affected areas, the spots were numerous enough to be readily observed by the owners. The overall average number of lesions per leaf in the most heavily affected area was estimated at less than one. However, many leaves had as many as ten or more spots but only a few leaves exhibited injury greater than 10% of the total leaf area.

Analysis of residues in the injured areas of the foliage, as well as other types of surfaces, was performed under an electron microscope equipped with an X-ray microprobe attachment. These analyses consistently showed that the residue contained large amounts of iron and sulphur with lesser amounts of copper, nickel and silicon as well as some plant

constituent elements. On the basis of such analysis, the Ministry of the Environment concluded that the causal agent was acidic particulate fallout that contained high concentrations of iron, nickel and copper sulphate (1). Wind patterns, elemental composition and episode timing pointed to the 381 m stack at Copper Cliff as the source of the fallout which damaged vegetation in southwest Sudbury. All incidents appeared to be associated with start-up, shutdown or some alteration in the production rate of the smelter.

A number of samples of vegetation were collected during the course of investigation of the complaints. The samples were dried, ground and processed for chemical analysis. The elements tested varied from year to year but included copper, nickel, and iron. A summary of the analysis is presented in Table 24.

Levels of lead and zinc were below the upper limits of normal concentration for all vegetation samples collected in association with black spot incidents. The most significant contamination of samples occurred with copper and nickel. All samples, except the controls, contained levels much higher than normal limits for these two elements. Other elements found elevated above the upper limits of normal

concentration in several samples were selenium, iron, cobalt, arsenic and sulphur. With the exception of iron and sulphur, all other elements were found in greater concentrations in samples from the affected area than from the control area.

Concentrations of the various elements varied with plant species. Many factors, such as leaf size, leaf texture and pubescence, can influence a plant's susceptiblity to fallout. Plant species also vary in their ability to uptake or bio-accumulate certain elements (2). It is not possible to eliminate uptake of these elements from the soil via the roots or contamination by various aerosols. It was noted, however, that onion foliage was fairly sensitive to fallout in 1978 episodes. Upper surfaces, which were directly exposed to the fallout, were severely injured while the lower, protected surface remained healthy. Samples of this foliage were collected and individual leaves split longitudinally into injured and uninjured portions prior to chemical analysis. The analysis of the duplicate samples of injured and non-injured onion foliage are shown below:

	ELEMENT (ug/g)					
Onion Foliage	Cu	Ni	Fe	As	Se	Pb
Injured	193	77	1200	4.9	265	16
Non-Injured	17	14	310	1.0	.91	6

Since the upper, injured portions of the leaves contained higher concentrations of copper, nickel, iron, arsenic, selenium and lead, then it appears that the fallout was directly contaminating the samples. Washing of samples before processing significantly reduced metal content of black spotted foliage; this also supports direct atmospheric deposition as the source of the elevated foliar metal content.

ii) Sulphur Trioxide Injury

A spill of SO_3 occurred at 9:10 a.m. on August 19, 1987. Approximately 2.5 tonnes of SO_3 were released over an 8 minute period from the Inco sulphuric acid plant. This release was allegedly the result of a power shortage which resulted in pump shutdowns. Wind was out of the west at 10-15 km/hr. Staff from the Ministry's Pesticides and Terrestrial Effects Unit carried out an extensive study to determine the effects of the SO_3 on vegetation in this area.

A total of 39 public complaints related to possible vegetation damage from the SO_3 spill resulted. Sulphur type injury was found on vegetation at 22 of these complainants properties. The majority of the injury was light and was found on scattered trees (white birch, trembling aspen and red oak) and garden

plants (bean, cucumber and tomato) between the Acid Plant and the Richard Lake/McFarlane Lake area. Sulphur-type injury was also found in a garden in the Wanup area (25 km east of the acid plant) and also in the St. Charles area (60 km east of the acid plant). Locations where sulphur-type injury was observed on vegetation are shown in Figure 4.

The injury symptom most commonly observed was that of an interveinal necrosis or browning on the foliage. It is suspected that an additive effect of sulphur dioxide (SO_2) emissions from the Inco superstack contributed to the overall injury.

There is a wide range of tolerance to sulphur injury between plant species and within species. This accounts for the scattered nature of the observed injury. No injury or injury pattern could be detected by aerial reconnaissance. Only light sulphur injury was noted on more sensitive plants due to the short duration of the fumigation. The SO_3 fumigation duration was between five and ten minutes. This time factor limited the effect of the fumigation.

iii) Ozone Injury

Ozone and other oxidant gases are formed in polluted atmospheres as a result of a wide variety of photochemical reactions involving reactive hydrocarbons and the oxides of nitrogen. Ozone can be transported over long distances along with the movement of large air masses within which it was formed. At sufficient concentrations and durations, ozone can cause toxicity to susceptible vegetation. The provincial criterion is 80 parts per billion (ppb) for one hour and is based on prevention of vegetation injury.

Injury symptoms, typical of those caused by ozone, were observed on the foliage of several vegetation species growing in the Sudbury area in July 1978. Two of the observed sites of injury involved complainants who alleged that emissions from Inco had caused the damage. A brief survey of the Sudbury area was undertaken and injury was observed at each of the locations examined. Overall damage was generally rated as moderate at locations south and west of Sudbury, whereas injury at the sites to the north and east were rated as trace to light. These sites are shown in Figure 5.

The most severe injury symptoms were oberved on sweet corn and grape, although injury was also recorded on potato, tomato, onion, bean, cucumber, zucchini, radish, petunia, pansy and Manitoba maple at one or more of the sites.

In July 1978, there were 17 hours when the ozone concentrations exceeded the provincial criterion of 80 ppb for one hour (Table 25). This is consistent with the appearance of the injury symptoms.

In early 1979, a number of complaints were received in early June. Over a wide area around Sudbury (as far south as Noelville and as far east as Verner), gardens were found to have a similar set of injury symptoms. The species most affected were bean, cucumber and to a lesser extent, tomato. The symptoms were mainly present as an extensive glazing or silvering of the cotyledons or first true leaf (this was the stage of maturity at the time). This glazed tissue soon dried and turned brown (necrotic), and the plants that survived were stunted. Disease and frost injury were discounted as possible causes for the injury. At that time, however, there were several hours when the ozone concentration at Sudbury exceeded the Ontario criterion of 80 ppb (Table 25). The cause of the observed injury was attributed to these increased ozone levels.

Although there have been over 100 hours of ozone concentrations in excess of 80 ppb during the growing seasons from 1975 to 1987, the episodes were substantially below the frequency and severity of episodes encountered in Southern Ontario where injury to cash crops has been significant (14). Nevertheless, major ozone episodes have been recorded in the early part of the growing season, and these concentrations were high enough to cause injury to vegetation in some years. The source of the ozone is believed to be long range transport.

iv) Road Salt Injury

Salt spray from de-icing salts will cause injury to vegetation. Evergreens growing adjacent to roadsides often exhibit necrotic foliage, particularly on the side of the tree facing the road. Generally, the amount of injury is related to the amount of salt applied and the volume of traffic. The distance to which the salt spray will travel is dependent upon the wind and exposure; however, in most cases, the major impact occurs within 50 to 100 m from the road. Certain species, such as white pine and red pine, have been shown to be more sensitive to salt spray than other species.

Salt spray injury to vegetation along the major traffic corridors into Sudbury has been reported (15).

In the spring of 1981, it was readily apparent that trees along the sides of Highway 69 from Lasalle Boulevard north to McCrea Heights had not developed normal foliage and salt spray was suspected as the causal agent. Most tree species in the vicinity of the highway were affected and included white birch, red maple, trembling aspen, pin cherry, large toothed aspen and showy mountain ash. The affected trees were located within 100 m of the highway and severity decreased with distance from the highway. Foliage on affected trees had not emerged to any significant extent except on lower branches which would have been covered by snow. The terminal buds were killed repeatedly for several years, and this had produced a tufted type of growth at the end of the branches.

Samples of twigs were collected for chemical analysis since foliage was not available near the highway. Using the highway right-of-way as a reference point, samples of white birch and trembling aspen twigs were obtained at 0, 50, 100 and 200 m from Highway 69 at one study location (Site A). At a second location (Site B), samples of twigs were collected at 0 and 150 m from the highway (Figure 6a). The samples were dried, ground and analyzed for Na, Cu, Ni, Zn, Co, Pb and Fe content.

The results of the analyses are presented in Table 26 and Figure 6b. In most cases, the twigs collected nearest the road contained higher concentrations of copper, nickel, lead, iron and sodium. Concentrations of these elements tended to decrease with distance from the road. Zinc and cobalt concentrations showed no pattern or relationship with distance from the road. The degree of contamination of twigs by the various elements was higher at Site A, which is more exposed, than at Site B.

Based on chemical analyses data, symptoms on the affected trees and the injury pattern in relation to Highway 69, it is concluded that the trees were affected by vehicular traffic. The elevated concentrations of sodium would indicate that road salt is the dominant contaminant involved; however, copper, nickel, lead and iron were involved to a lesser extent.

v) Nickel Toxicity

In the course of investigations of vegetation injury associated with complaints and regular programs, a few instances of nickel toxicity in oats or grass species were diagnosed. The symptoms in each case included strongly chlorotic areas (devoid of chlorophyll) between the veins of the leaves, similar to nickel toxicity symptoms described in the literature. In some samples, entire leaf blades

were affected. In most cases, the symptoms developed on young plants early in the growing season. The locations where such injury was observed are indicated in Figure 7.

The analyses of injured vegetation for nickel content are summarized in Table 27. Nickel content for plants collected in the field ranged from 58 to 154 ug/g (on a dried weight basis), and all samples contained higher concentrations of nickel than the upper limits of normal concentration guideline. At two locations (B and C), the soil was very acid and sandy and from fields which had not been in cultivation for a number of years. Although the concentrations of nickel in the soils from these sites was only slightly elevated, the combination of acid and sandy textured soil caused the nickel to be readily bio-available (and toxic) to the oats. In contrast, the heavier (higher clay content) and less acid soils at Sites D and E needed much higher total nickel concentrations before the toxicity symptoms developed.

Bulk soil samples from the area where the injured plants were observed were brought into the laboratory. Oat seeds were planted in containers of the soils and placed in the growth chamber. The young plants developed injury symptoms similar to those observed in the field and to the symptoms produced by plants growing in soil artificially contaminated by nickel.

The nickel content of plants grown in the growth chamber tended to be higher than the comparable field grown plants. The toxicity symptoms did not develop when crushed agricultural limestone was applied to overcome the acidity of the soil.

In summary, nickel toxicity symptoms were observed on grain and grasses growing at five locations in the Sudbury area. The toxicity was associated with high nickel content of the vegetation. Bio-availability of nickel to the plant was influenced by nickel content of the soil, soil texture and soil pH. Limestone applications to the soil could overcome the toxicity in laboratory tests.

vi) Grass Chlorosis in the Copper Cliff Area

Patches of chlorotic grass were noted in the Copper Cliff area between 1982-1984. In an effort to determine the cause of the chlorosis, grass and soil samples were collected for chemical analysis from several sites in the Copper Cliff area (Figure 8). Analytical results showed elevated levels of copper, nickel, cobalt, selenium, arsenic and sulphur in both soil and grass samples. The source of these elements was believed to be historical deposition from the smelter operations around Copper Cliff. Chemical analyses of the vegetation and soil are shown in Tables 28 and 29, respectively. More details of this study are given in a Ministry report (23).

Comparisons between metal levels in chlorotic and non-chlorotic grass, although not conclusive, tend to indicated increased levels of nickel, copper and selenium in chlorotic grass. Beckett and Davis (3) demonstrated reduced yields of barley at foliar concentrations of either 20 ug Cu g^{-1} or 26 ug Ni g^{-1}, both of which were greatly exceeded in the Copper Cliff area. The toxicity of copper and nickel have been found to be additive (6), and the combined effects of these elements would appear to be the most probable cause of the yellowing of grass in Copper Cliff. Metal toxicity is further supported by the field observation of typical nickel toxicity symptoms.

vii) Verticillium Wilt of Maple Trees

Following the investigation of several complaints concerning the wilting and dieback of silver maple trees in the City of Sudbury, it became apparent that additional trees were exhibiting similar symptoms. In light of these observations, a survey of the condition of maple trees on 40 streetside plantings was undertaken in June 1981. The survey consisted of counts of the numbers of trees exhibiting the wilting or flagging symptom on each street. Samples of wilted twigs were collected from 4 Norway maple and 17 silver maple trees in representative areas of the city. The condition of the sample tree crown was scored and the presence of olive-green staining in the sapwood or wilting of the tree was recorded.

The trees in question were of several age groups. In general, the older trees were in better condition than the younger trees. Particularly in the case of the silver maples, the terminal portions of branches were dead (20-50 cm) and appeared to be a normal problem of winter injury. In addition to the above condition, some trees exhibited flagging (wilting and dessication of the current year's foliage) of small to large branches. It is estimated that about 2-5% of all trees were affected by the wilting syndrome. A number of trees were found to have an olive-green stain in the sapwood. This stain, as well as the wilting symptoms, are typical of Verticillium wilt.

A total of 78 silver maple and 9 Norway maples were found with wilt symptoms. These were planted primarily in the years 1964, 1967 and 1968, and were more numerous on Redfern, Auger, Velray and Robin Streets.

viii) Miscellaneous Injuries

For a number of years, young white birch trees have been observed to have an unusual set of foliage injury symptoms. A slightly different set of symptoms (but possibly caused by the same agent(s)) has also been found on red maple. The injury has

only been observed in the Sudbury area. Affected trees typically display moderate to severe marginal chlorosis and bleaching of the foliage. Frequently, the marginal tissues turn brown and die. The affected trees are most frequently encountered on, but are not confined to, shallow, well drained soils. The symptoms can be distinguished from leaf yellowing and abrasion caused by drought conditions. The exact cause of the injury syndrome has not been determined despite investigation by several agencies. It is quite probable that a combination of conditions or factors are required before the symptoms develop. Chemical analysis of foliage and other samples suggest that magnesium (and possibly calcium) is deficient and the condition is exacerbated by higher than normal copper and nickel concentrations. Metal uptake by plants is enhanced by low pH soils which are common in the Sudbury area. Much of the data collected during the various investigations of this phenomena has been compiled in another report (16).

Many injuries to vegetation were found to be caused by common diseases and insects. These occurred regularly on their respective host plant species. The less common problems included an outbreak of Manitoba maple leaf roller in the City of Sudbury in 1981. Also in 1981, barley, oats and wheat crops were frequently found to show symptoms of infection

by the barley yellow dwarf virus. In 1982, an outbreak of woolly alder aphid was encountered on silver maple in the City of Sudbury. In 1975, 1982 and 1987 very low rainfall levels were recorded during the growing season (Table 30). Certain types of vegetation, especially those on exposed dry sites, suffered a great deal from drought stress. It is not expected that any of the injuries noted above would have any long-term effect on the vegetation.

IX. SAMPLING AND CHEMICAL ANALYSIS OF VEGETATION AND SOIL - REGULAR PROGRAM (1970-1984)

a) Program Outline

During the 1970 growing season, the Ministry of the Environment established 15 permanent vegetation and soil sampling plots in the territory potentially affected by the Sudbury area smelters and two control plots in areas remote from Sudbury. Since that time, four additional plots have been established at various locations. The following table lists the location of each plot, the year of establishment and the distance and direction of the plot from the City of Sudbury. The locations of the sampling sites are shown in Figure 9.

Plot Location	Year Established	Distance and Direction from Sudbury
Blind River	1970	160 km W (Control Plot)
Mattawa	1970	176 km E (Control Plot)
Sudbury	1970	0 km
Garson	1970	5 km NE
Skead	1970	26 km NE
Kukagami Lake	1970	42 km NE
Grassy Lake	1970	64 km NE
Lake Temagami	1970	80 km NE
Callum	1970	29 km E
Sturgeon Falls	1970	77 km E
St. Charles	1970	28 km SE
Burwash	1970	27 km S
Tilton Lake	1973	15 km SW
Lake Penage	1970	37 km SW
Killarney Park	1972	64 km SW
Nairn Centre	1970	48 km WSW
Fairbanks Park	1973	39 km W
Rayside Township	1970	16 km NW
Morgan Township	1970	24 km NW
Milnet	1970	37 km N
Chiniguchi Lake	1973	57 km NNE

Foliage samples of several vegetation species and soil samples (0-10 cm) were collected at each site. Initially, the samples were analyzed for sulphur, copper, nickel, iron, selenium, arsenic, cobalt and fluoride. Each year the chemical analysis data have been examined, and as a result certain modifications have been made in the program. Additional sampling sites have been established, other chemical analyses discontinued, some analyses initiated and the sampling of some plant species discontinued. In 1971, 1972 and 1973, the sampling was carried out during June, July and August. Analysis for fluoride was discontinued in 1971.

In 1974, sampling was reduced to include only trembling aspen and soil (0-10 cm) which were analyzed for total sulphur, copper, nickel, iron and arsenic, in June, July and August. In 1975, 1976, 1979 and 1987 triplicate samples of white birch foliage and triplicate soil samples were collected at each sampling site in July and August. The samples were analyzed for sulphur, copper, nickel, iron, arsenic and lead in all years.

In years prior to 1975, the analyses were performed on "washed" samples. Experience has shown that the washing procedure did not significantly alter the concentrations of elements in vegetation, and therefore, washing of samples was discontinued.

Soils were analyzed for the same elements as vegetation plus pH, total calcium content and total magnesium content.

b) Trace Metal Emissions in the Sudbury Area

On the basis of a number of emission rate studies conducted by the Ministry in co-operation with Inco Ltd. and Falconbridge Ltd. during the period 1973-1981, it was determined that iron, copper, nickel, lead and arsenic were the major elements emitted from smelting operations (27, 28). It was further determined that elements such as zinc, aluminum, chromium, cadmium, magnesium, manganese, cobalt and selenium were also present in the emissions but in considerably lower amounts.

The average emission rate of particulate emissions (and consequently of trace elements) is believed to have decreased since the 1970's, in conjunction with restrictions in SO_2 emissions. Table 31 summarizes some of the data from the Inco Ltd. tall stack (27). It should be emphasized that the data measurements are accurate to only within a factor of two; however, there appears to exist a downward trend in emissions and hence in the deposition rate of metals in the Sudbury basin, as a function of time.

c) Elemental Analysis of White Birch Foliage

i) Copper

Copper concentrations in the white birch foliage were found to fluctuate from year to year; however, there are several conclusions which can be made regarding the data. In most years, the highest copper concentrations were encountered at Garson, Skead and Sudbury (Table 32). In 1970, only samples from those sites farthest from Sudbury (Blind River, Mattawa, Grassy Lake, Sturgeon Falls, St. Charles, Nairn Centre and Morgan Township) had copper contents below the upper limits of normal concentration guideline of 20 ug Cu/g. Since 1976, the number of exceedences of the normal concentration guideline has decreased, with only samples from the Garson and Sudbury sites in 1984 exceeding the guideline.

ii) Nickel

The normal concentration guideline of 30 ug nickel/g tissue was exceeded in all years at the Sudbury, Garson, Skead and Rayside Township sites (Table 33). They were exceeded in samples collected at Milnet in 1970, and at Kukagami Lake and Burwash in all years except 1979 and 1984. Tilton Lake samples were above normal for all years except 1979. Nickel concentrations remained fairly constant at most sites from 1970 to 1973 then increased in 1975 and 1976. In later collections, the values decreased until the lowest values were measured in the 1979 or 1984 samples.

iii) Arsenic

Normal concentration guidelines (2 ug/g) for arsenic in white birch foliage were exceeded at only four sites (Skead, Kukagami Lake, Garson and Sudbury) (Table 34). This occurred in each year from 1970 and 1975 at Skead but only in 1970 at Kukagami Lake. The other exceedences were at Garson in 1971 and 1975 and at Sudbury in 1971. The latest collections (1979, 1984) generally showed the lowest arsenic content.

iv) Selenium

The analytical data for selenium are included in Table 35. In all samples taken in 1970, selenium values exceeded the normal concentration guideline of 0.5 ug Se/g tissue. Comparison with the control sample collected at Mattawa indicated, however, no difference between sites affected by Sudbury emissions and those unaffected. Above normal selenium content was also found in 1984 foliage samples from the Sudbury, Rayside Township, Tilton Lake and Garson sites. These 4 sites are among the closest to the Sudbury smelter complex. Although selenium concentrations were the highest in 1984 at these 4 sites, 12 of the remaining 17 sampling sites produced the lowest measured levels of selenium in foliage.

vi) Iron

The iron content of birch foliage samples are presented in Table 36. In nearly all cases, the values were below

the normal concentration guideline of 500 ug Fe/g tissue. The two exceptions were for samples collected at Temagami and Morgan Townships, both in 1975. There is no apparent relationship of iron values to proximity to the smelters in the Sudbury area based on these data. There was a large amount of variability from year to year, even at the control sites, and no conclusive trends could be derived. High variability of iron content in soil is common thus iron content in foliage uptaken from soil is expected to be variable.

vi) Lead

The lead content of all white birch foliage samples were within the normal concentrations and no samples exceeded the guideline of 30 ug/g (Table 35). The lowest values were found in 1984 in nearly all instances, indicating a decrease in lead content of foliage in recent years.

vii) Sulphur

The sulphur content of white birch foliage is presented in Table 38. All post 1971 samples were found below the normal concentration guidelines of .4% S in tissue. Generally, sulphur content of birch leaves has declined since the early 1970's. This corresponds to the declining number of potentially injurious fumigations (Table 22). Sulphur content from most Sudbury sites, with the exception of Skead and Garson (closest downwind sites), were comparable to the control values for the later collections.

viii) Summary of White Birch Foliage Analysis

The upper limits of normal concentration for copper and nickel in white birch foliage were commonly exceeded at Sudbury, Garson, Skead and, less often, at slightly greater distance from the smelter (Rayside Township, Tilton Lake, Callum and Kukagami Lake). The later collections (1979, 1984) of birch foliage had lower content of nickel and copper at most sites compared to earlier collections. Above normal arsenic content in foliage was noted in pre-1976 samplings at 4 sites (Sudbury, Garson, Skead and Kukagami Lake). The more recent collections showed a decrease in foliar arsenic content. Concentrations of selenium were found to be above normal in all samples collected in 1970, including a control sample, and at 4 sites in 1984 (Sudbury, Garson, Skead and Tilton Lake). The majority of sites had lower foliar selenium content in the latest collections (1979, 1984). All birch leaf samples collected after 1971 contained normal concentrations of sulphur. Lead and iron concentrations were within normal limits and no trend with distance from the smelter was apparent.

Particulate emissions are believed to have decreased since the 1970's in conjunction with reductions in SO_2 emission. This is reflected in foliar content of copper, nickel and arsenic.

d) Elemental Analysis of Forage

i) Copper

The concentrations of copper found in grass foliage are shown in Table 39. The normal concentration guideline of 20 ug Cu/g tissue was exceeded only at Garson (1970, 1972 and 1974) and at Skead (1970, 1974). Up to 1974, the copper content of the forage indicated some relationship with proximity to the smelters with samples at the closer sites having the higher values. In the 1979 and 1984 collections, the concentrations of copper decreased, especially at the sites nearest to the smelters, to such an extent that the smelter influence on the copper content of the forage has been considerably reduced.

ii) Nickel

The nickel contents of grass samples, which are shown in Table 40, exceeded the normal concentration guideline of 25 ug Ni/g tissue in nearly 25% of the collections. These exceedences occurred fairly consistently at Sudbury, Garson, Skead and Callum. Normal concentrations were exceeded in individual years at Milnet (1970), Burwash (1974), Tilton Lake (1974, 1984), Morgan Township (1972) and Kukagami Lake (1971, 1974). At Rayside, the normal concentration guidelines was exceeded in 1970, 1972 and 1973. At some sites, nickel values appeared to decrease in the 1979 and 1984 collections but this was not consistent for all sites. Nickel values showed a decreasing gradient with distance from the smelters in the Sudbury area.

iii) Arsenic

The arsenic in samples of grass foliage did not exceed the normal concentration guideline of 8 ug As/g tissue (Table 41). Arsenic values greater than 2 ug As/g tissue were found at Sudbury (1971, 1972, 1973), Garson (1970, 1971, 1972) and Skead (1971, 1974). The highest concentration was measured in 1971, but it decreased with time to 1979, where many values were at or near the analytical detection limits. Improved analytical methods reduced the detection limits in 1984, and all but three sites had forage with less than 0.3 ug As/g.

iv) Selenium

The normal concentration guideline of 0.5 ug Se/g tissue was exceeded at most locations in 1970 (Table 42). These included Mattawa (a control), Garson, Skead, Kukagami Lake and Lake Penage. The only other occasions when the guideline was exceeded was at Skead (1973) and Garson (1984). The lowest forage selenium content was found in the latest collection (1984) at 17 of the 21 sampling sites.

v) Iron

The iron concentrations in forage (Table 43) show variability from site to site and year to year. There is no apparent trend that would relate the collection site location with respect to the smelters.

Only samples collected at Chiniguchi Lake in 1979 exceeded the normal guideline of 500 ug Fe/g tissue.

vi) Lead

The normal concentration guideline of 20 ug Pb/g tissue was not exceeded in any forage sample (Table 44). Values of lead measured at most sites decreased over time with the lowest values in the 1984 collection, and no differences were evident between the test plots and the controls. Lead values showed no relationship to locations with respect to the Sudbury area smelters.

vii) Sulphur

The normal concentration guidelines of .5% was not exceeded in a forage sample (Table 45). As was the case with white birch foliage sulphur, content has decreased since the early 1970's at most sites. Four Sudbury sites (Lake Temagami, Burwash, Tilton Lake and Fairbanks Park) did however produce the highest forage sulphur content in 1979. This is unexpected since there were low SO_2 emissions in 1979 due to an extended Inco strike.

viii) Summary of Forage Analysis

Above normal concentrations of nickel in forage were frequently found at 4 sites (Sudbury, Garson, Skead and Callum). Elevated copper levels in forage were mainly experienced in collections during the early 1970s. Lead, arsenic and iron concentrations were within normal limits for forage. The content of nickel, copper, selenium and

arsenic in forage was lower in the later collections (1979, 1984) for most sites, and even though the control plots exhibited a similar trend, these results are believed to be the result of decreased SO_2 emissions. Only one site was found with above normal iron content in forage (Chiniguchi Lake). All forage samples had normal lead and sulphur concentrations. Lead and iron values showed no trend with respect to distance or direction from the Sudbury area smelters.

e) Elemental Analysis of Soil

i) Copper

The concentrations of copper found in soil samples in the Sudbury area are presented in Table 46. The normal concentration guideline of 60 ug Cu/g soil (0-5 cm) was frequently exceeded. Surface soils at the Sudbury, Tilton Lake and Skead collection sites contained over 100 ug Cu/g soil in most cases. At Garson, the soils exceeded the guideline each year except 1972 and 1974. At Kukagami Lake, the guideline was exceeded in 1970, 1972, 1976, 1979 and 1984. This was similar to data for Callum except that the guideline was exceeded in 1975 and not in 1976. At this location, the copper values were elevated at all soil depths. Copper concentrations exceeded the guideline at Lake Penage in four years

(1971, 1975, 1976, 1979) and at Nairn Centre in 1973. With the exception of 1971 and 1979 the guideline was exceeded at Rayside each year.

The data show that the soils nearest to the Sudbury area smelters contained the highest copper content and that it decreases with increasing distance from Sudbury. The data for the samples collected in 1979 and 1984 demonstrated that the highest degree of contamination was present in the surface horizons.

ii) Nickel

The normal concentration guideline of 60 ug Ni/g soil was exceeded in one or more years at 12 of the sampling stations (Table 47). The soils at Sudbury, Garson (except 1974), Skead, Tilton Lake and Rayside Township (except 1971 and 1979) consistently exceeded the guideline. At Kukagami Lake, the guideline was exceeded in 1970, 1972, 1975, 1976, 1979, and 1984. It was also exceeded at Grassy Lake (1970, 1975), Temagami (1976), Callum (1972, 1975, 1979, 1984), Burwash (1973, 1976, 1984) and Penage (1970, 1975, 1979, 1984). The higher nickel values were related to proximity of the sampling sites to the smelters in the Sudbury area. Nickel concentrations decreased with increasing soil depth as shown by the 1979 and 1984 collections.

iii) Arsenic

Table 48 shows arsenic concentrations measured in soils collected in the Sudbury area. The highest values exceeded the normal concentration guideline of 10 ug As/g soil (0-5 cm) at sites nearest to the smelters. Concentrations over 40 ug As/g soil were found at Skead in 1971 and 1972. It was only in 1973 that the guideline was not exceeded at Skead. The guideline was exceeded at Sudbury (1970, 1971, 1972, 1975, 1979, and 1984) Garson (1971, 1973, 1975, 1979), Kukagami (1970, 1972, 1984), Grassy Lake (1972), Callum (1970) and Tilton Lake (1975, 1979). Samples collected in 1979 and 1984 generally showed a trend of decreasing arsenic content with depth. Arsenic values were quite variable over the years at each site including the control sites. Soil samples collected in 1984 had the highest arsenic content at 4 sites (Sudbury, Milnet, Kukagami Lake and Burwash) and were comparatively high at several other sites.

iv) Selenium

The normal concentration of 2 ug Se/g soil was exceeded in 1984 at the following locations: Sudbury, Tilton Lake and Penage Lake (Table 49). Values measured in 1984 were the highest measured at 18 of the 21 sampling locations.

v) Iron

The normal concentration guideline of 3.5% Fe in soil was not exceeded in any soil sample (Table 50). The iron concentrations displayed variability from site to site and year to year. There was also variability in iron content in soil between the different depths sampled at each site in 1979 and 1984. There is no apparent overall trend that would relate the sample site location with the smelter emissions.

vi) Lead

The lead content of all soil samples were within levels considered to be normal, and no samples exceeded the guideline of 150 ug Pb/g soil (Table 51). There was no apparent trend or gradient relating concentration to distance or direction from the smelters. The surface (0-5 cm) soil samples consistently had higher lead concentrations than the deeper soil samples (5-10 cm, 10-15 cm) for 1979 and 1984.

vii) Calcium and Magnesium

Calcium and magnesium concentrations measured in the soil samples collected in the Sudbury area are presented in Tables 52 and 53, respectively. No soil sample contained excessive concentrations of calcium (3%) or magnesium (1%). Generally higher values for both calcium and magnesium in surface soil were measured in 1979 and 1984, whereas the lowest values came in 1973. However, similar trends were observed in the controls. Values for both elements are considered low, and there was considerable variability in concentration.

viii) Sulphur

Sulphur concentrations measured in soil samples are presented in Table 54. Only 3 samples (2 at Skead and 1 at Kukagami) contained sulphur concentrations greater than the normal concentration guideline of 0.10%. The majority of the samples contained sulphur in amounts similar to or slightly greater than control samples.

Samples of soil taken at 3 depths (0-5 cm, 5-10 cm, 10-15 cm) in the 1979 and 1984 collections contained similar amounts of sulphur. The surface level (0-5 cm) contained slightly higher sulphur content in more than half the samples.

ix) Soil pH

A summary of the pH values measured in soil samples collected in the routine Sudbury locations between 1970-79 is presented in Table 55. From these data, there does not seem to be a distinct trend in soil pH over time. Unpublished work and opinions of local scientists point towards a gradual increase in soil pH since the construction of the Inco tall stack in Copper Cliff. Future work on soil pH in the Sudbury area will be incorporated into the Ministry's surveillance program. In many of the lakes in the Sudbury area, there have been observed increases in pH and decreases in SO_4 and trace metal concentrations reflecting reduced contaminant deposition from the Sudbury smelting industry, since patterns of change bear general relationships to distance from the Sudbury smelters (10).

x) Summary of Soil Analysis

Elevated content of copper and nickel were frequently found in surface soil collected at the closest sites to the smelters (Sudbury, Garson, Skead). Above normal concentrations of these elements were also found in some samples collected at slightly greater distances from the smelters (Rayside Township, Tilton Lake, Kukagami Lake). Most soil samples collected in the Sudbury area contained much higher nickel and copper content in relation to the control samples, and concentrations generally increased with decreasing distance from the smelters.

Amounts of arsenic in surface soil were found to exceed the contaminant guideline value at those sites nearest the smelters. Arsenic content was the highest in 1984 at 4 sites (Sudbury, Milnet, Kukagami Lake and Burwash). Selenium content was also found to be the highest measured at most of the sites in the 1984 collection. Three sites in the 1984 collection were found with above normal selenium content (Sudbury, Tilton Lake and Penage Lake).

The content of sulphur in soil was found higher than normal only in 3 samples (2 from Skead and 1 from Kukagami).

The content of lead, iron, calcium and magnesium was present within levels considered normal. There was no apparent trend or gradient relating to distance or direction from the smelter with these elements.

The level of calcium and magnesium was higher at most sites (including the controls) in the later collections.

Concentrations of nickel, copper, arsenic, selenium and lead generally decreased with increasing soil depth.

X. MOSSBAG SURVEYS

a) Methods

Various studies have shown that the surface ion exchange capacity of sphagnum moss can be used as a tool for monitoring airborne contaminants. By exposing known quantities of the moss at various locations using standard techniques, a pattern of distribution of airborne contaminants can be developed. The mossbag technique was used for such a purpose in the Sudbury area in 1976 and 1977. A total of 19 locations were selected as sites to expose sphagnum moss monitors in 1976. This number was expanded to 47 monitoring locations in 1977 (Figure 10). The locations of the sites were as follows.

Site No.	Location
M1	Southview Drive, Sudbury
M2	Morrison Street, Gatchell
M3	Ash Street API Station
M4	Roman Catholic Cemetary, Lasalle Blvd., Sudbury
M5	New Sudbury API Station
M6	Herbert Street, Sudbury
M7	Laurentian University, Sudbury
M8	Silver Lake, Sudbury
M9	Southview Drive at Sudbury Bypass
M10	Lake Penage SO_2 Monitor Station
M11	Cobalt Street, Copper Cliff
M12	Rayside SO_2 Monitor Station
M13	Notre Dame Street, Hanmer
M14	Skead, SO_2 Monitor Station
M15	Happy Valley SO_2 Monitor Station
M16	Garson SO_2 Monitor Station
M17	Callum SO_2 Monitor Station
M18	Coniston API Station
M19	Burwash SO_2 Monitor Station
M20	Wanup
M21	Wanapitei
M22	Garson Gun Club Road
M24	Garson North (Garson Mine)
M25	Bailey's corners
M26	4 km North of Falconbridge

M27	West Bay, Lake Wanapitei
M28	Radar Station, CFB Falconbridge
M30	Capreol
M31	Phillippe Street, Val Therese
M32	Main Street, Val Caron
M33	McCrea Heights
M34	Morgan SO_2 Monitor Station
M35	Main Street, Chelmsford
M36	Notre Dame Street, Azilda
M37	Clarabelle
M38	Cinnottiville
M39	George Street, Lively
M40	Simon Lake Road, Naughton
M41	Cemetary, Whitefish
M42	Black Lake
M43	Dew Drop Road, Long Lake
M44	Wavy Lake
M45	MacFarlane Lake
M46	Kukagami Lake Road
M47	Chiniguchi Lake SO_2 Recorder Station
M48	Grassey Lake SO_2 Recorder Station
M49	Lake Temagami, Bear Island, SO_2 Recorder Station

Each monitor or mossbag consisted of a thin layer of moss (3.0 g in 1976, 5.0 g in 1977) sewn into a pocket of nylon screening, measuring 8 cm x 5 cm. The mossbags were attached by wooden holders at a height of 2 meters to wooden poles or trees. The holders consisted of a short board with wooden spacers fixed to each end such that the moss did not touch the board (Figure 11). The bag was held in place by sandwiching the edge of the bag between "velcro" strips, one of which had been glued to the spacer. Exposed mossbags were replaced with fresh, unexposed mossbags at approximately four-week intervals to cover the months of July, August, September and October in 1976 and June, July, August and September in 1977. All moss in the mossbags was dried, ground and submitted for chemical analysis on a dry weight basis for copper, nickel, iron, cobalt, arsenic and lead (1977 only). Blank (unexposed) mossbags were periodically

submitted as check samples. For purposes of interpreting the data in this report, all mossbag data were considered together to establish concentration ranges of the respective elements. From these concentration ranges, it was possible to group the different monitoring sites on the basis of whether the samples exposed at these sites in one or more months had accumulated amounts of the various elements in excess of arbitrarily selected concentrations. The concentrations selected for grouping sites are as follows:

Element	Selected Concentrations (ug/g)
Copper	50 - 100
Nickel	50 - 100
Cobalt	5 - 10
Iron	1000 - 2000
Arsenic	1.5 - 3
Lead	60 - 75

b) Elemental Analysis of Mossbags

The results of the chemical analyses of the moss in mossbags are presented in Tables 56 to 61. Some mossbags were lost or destroyed at various times; however, the majority of the possible data was available for interpretation.

Concentrations of the different elements varied from month to month at each site and more variability was noted within years than between years. Those sites where a high degree of contamination of the moss was measured usually showed contamination in all months of exposure of the moss.

i) Copper

Copper concentrations in moss exposed at Sites M3, M9, M15, M37, and M38 were consistently in excess of 100 ug Cu/g moss (Table 56). The highest single value of 1260 ug Cu/g was measured at Site M37. A total of 15 sites had copper concentration values over 100 ug Cu/g moss on one or more occasions. The distribution of these 15 sites indicates that they can be arranged in two separate groups (Figure 12). Nine sites, mainly to the east of Copper Cliff, appear to be associated with the Inco operation. The remaining six sites are associated with the Falconbridge operation, although the high concentration measured at Coniston in one month is mainly related to dust blown from the industrial barrens in that area.

With the exceptions of Sites M16 and M39, a number of sites surrounding the areas covered by the 15 sites noted above can be grouped on the basis that copper concentrations of 50 ug Cu/g moss were measured on one or more occasions (Figure 12). In addition, Site 10 (Lake Penage) and Site 19 (Burwash) showed copper concentrations in excess of 50 ug Cu/g moss on one occasion each, but contamination of these sites did not appear to be continuous with contamination at the other areas surrounding the smelter operations.

ii) Nickel

Concentrations of nickel in moss exposed at Sites M15, M26, M37, and M38 were frequently in excess of 100 ug Ni/g moss (Table 57). The maximum values measured (up to 980 ug Ni/g moss) were monitored at Site M15 (Happy Valley). At a total of eight sites, concentrations of nickel in excess of 100 ug Ni/g moss were found on one or more occasions. Four of these sites were associated with Inco operations at Copper Cliff while the remaining four sites were associated with Falconbridge operations. At several additional sites in proximity to the eight sites noted above, nickel concentrations were found to be in excess of 50 ug Ni/g moss on one or more occasions (Figure 13). The two groups of sites, where elevated concentrations of nickel was monitored, were associated with the smelter operations at Copper Cliff and Falconbridge, respectively. In addition, mossbag monitors at Sites 10 and 19 (Lake Penage and Burwash, respectively) were found to have accumulated nickel in concentrations over 50 ug Ni/g moss on one occasion each. Contamination at these sites does not appear to be continuous with contamination measured in the area around the smelter operations.

iii) Cobalt

Cobalt concentrations over 10 ug Co/g moss in exposed mossbags were found at seven locations (M3, M9, M14, M15, M26, M37 and M38), on one or more occasions (Table 58). The highest concentrations of cobalt were measured at Site 15 (Happy Valley). At an additional seven sites, cobalt concentrations exceeded 5 ug Co/g moss on one or more occasions. The sites where elevated cobalt concentrations were measured could be grouped in areas associated with Copper Cliff or Falconbridge smelter operations (Figure 14).

iv) Iron

The iron content of moss exposed in mossbags is summarized in Table 59. The highest concentrations of iron (up to 4,800 ug Fe/g moss) were found in samples exposed at Site 15 (Happy Valley). Concentrations of iron over 2,000 ug Fe/g moss were found at four sites (M14, M15, M18, M26) associated with Falconbridge on one or more occasions. The majority of monitoring sites were found on one or more occasions to have exposed moss samples which contained over 1,000 ug Fe/g moss (Figure 15). Those sites which did not have a single moss sample with over 1,000 ug Fe/g moss were generally those which were most distant from Sudbury.

v) Arsenic

The concentrations of arsenic in moss exposed in the Sudbury area are presented in Table 60. Moss contained over 3 ug As/g moss on at least one occasion at nine sites. The highest arsenic concentrations were measured in samples exposed at Site M15 (Happy Valley). Six of the nine sites noted above were associated with the Falconbridge operation, two were associated with the Copper Cliff operation while the remaining site (Site 5) was approximately equidistant from these two operations (Figure 16). A number of samples of moss contained over 1.5 ug As/g moss on one or more occasions, and these sample locations were generally closer to the two centres of smelter operation than those sites where no sample contained over 1.5 ug As/g moss. The exception to this is that samples from each of the Lake Penage (Site 10) and Burwash (Site 19) sites contained elevated concentrations of arsenic on one and two occasions, respectively.

vi) Lead

Lead analysis data for moss bags exposed in the Sudbury area are available only for the 1977 program (Table 61). Lead concentrations over 100 ug Pb/g moss measured only at Sites M15 and M22, both of which are associated with the Falconbridge smelter operation (Figure 17). At three additional sites (M14, M37, M45) exposed moss contained over 75 ug Pg/g moss but only at Site M37 and M45 was there any direct exposure to automobile emissions.

Mossbags at several other locations with equal opportunity for exposure to automobile emissions did not accumulate the same amounts of lead as mossbags exposed at Sites M37 and M45. Lead concentrations in moss over 60 ug Pb/g moss show two zones of lead accumulation generally associated with the smelter complexes at Copper Cliff and Falconbridge.

vii) Summary and Discussion of Mossbag Surveys

A program to monitor the distribution of airborne metals in the Sudbury area was carried out in 1976 and 1977. Mossbag monitors, containing fixed amounts of sphagnum moss, were set out of 19 locations in 1976, and 47 locations in 1977. After exposure for approximately one-month periods, the moss was analysed for copper, nickel, cobalt, iron and lead (1977 only).

An examination of the data obtained from the monitors indicated that each of the elements for which analyses were made, were accumulated in the moss. The patterns of accumulation indicated that elevated concentrations of copper, nickel and cobalt were centred at Copper Cliff and Falconbridge and that they decreased with increasing distance from these centres. Iron was accumulated in the greatest quantities of any of the elements tested and

over the widest area. The greatest accumulation of iron in the moss was at sites associated with the Falconbridge smelter. The highest concentrations of arsenic were measured at Happy Valley, and the pattern of arsenic accumulation suggested that the Falconbridge operations was a significant source of this element. The pattern of lead accumulation was not as clear as the pattern for the other elements; however, the highest lead concentrations measured were associated with the Falconbridge operation.

Copper, nickel, cobalt and arsenic were found in slightly elevated concentrations on one occasion at Lake Penage and Burwash. Iron and lead were also elevated at Lake Penage on one occasion. The source of the metals which were accumulated at these two sites is not known since both sites appear to be outside of the area of primary influence from the smelter complexes at Copper Cliff and Falconbridge.

If the capture efficiency of each of the different airborne elements by the mossbags is similar, then the relative amounts of each element measured in the moss can be considered as a measure of the amounts of each element in the air in the Sudbury area for the monitoring periods.

Iron, copper, nickel, lead, cobalt and arsenic (in descending order of prevalence) were present in the air. Air quality obtained by high-volume air sampling techniques (22) and emissions data (26) support the mossbag data.

The mossbag technique appears to be useful in determining patterns of contamination by airborne elements. Although the technique cannot measure the actual concentration of any element in air, it can be used as a relatively inexpensive method of determining patterns of airborne contamination upon which to plan air sampling programs using more accurate but more costly monitoring devices (i.e. high volume air samplers). However, this method combines current airborne concentrations and entrainment of historical deposition. Consequently, it cannot be used to quantify airborne concentrations from current emissions alone.

XI. LAND RECLAMATION SUMMARY

Any report on studies of the terrestrial environment of the Sudbury area would not be complete without some reference to the land reclamation activities that have taken place in recent years. Following the improvement in the local air quality, as already described in this report, it became possible to re-establish a vegetation cover on previously damaged sites. The following synopsis was taken from a summary report of the land reclamation program prepared by the Regional Municipality of Sudbury (25).

Large scale land reclamation in the Sudbury area began in 1978 using technology developed by Laurentian University and by Inco Ltd. The project was carried out under the guidance of the Vegetation Enhancement Technical Advisory Committee (VETAC) of the Regional Municipality of Sudbury. The VETAC group consists of volunteer members representing Laurentian University, the Regional Municipality, Inco Ltd., Falconbridge Ltd., Ontario Ministry of Natural Resources, Nickel District Conservation Authority, Ontario Ministry of Northern Affairs, Sudbury Horticultural Society, area Municipalities and the Ontario Ministry of the Environment.

Land reclamation activities have been carried out each year since 1978. Funding was derived from a variety of sources to employ students and unemployed or laid off workers for nearly 39,000 work weeks over a period of six years. Total cost of the program 1978 to 1983 amounted to about $12 million.

The reclamation involved mainly the application of agricultural limestone to areas which had previously shown environmental disturbance and loss of vegetation due to historical, mining-related activities. The limestone was used to neutralize soil acidity and render the metals in the soil less toxic to vegetation. The liming activity was followed by application of fertilizer and a grass seed mixture. A number of smaller projects to monitor the success of the work, to carry out experimental work and to document the project activities were associated with the overall program (Table 62).

To say the least, the reclamation work has been highly successful in establishing a vegetation cover on over 2,600 ha of treated areas. It has been noted that natural establishment by native trembling aspen and seedlings of other tree species is taking place. This growth has been supplemented with over 850,000 nursery grown trees. The reclamation program has been successful in improving the visual appearance of the Sudbury area as well as providing temporary employment and increasing the civic pride of the citizens in the area.

XIII. ACKNOWLEDGEMENTS

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XII. BIBLIOGRAPHY

1. Anonymous, 1978. Report on particulate deposition in Sudbury, August 30, 1978, and September 8, 1978. Ontario Ministry of the Environment, Northeastern Region, Sudbury, Ontario.

2. Beaton, J. D., 1966. Sulphur requirements of cereals, tree fruits, vegetables and other crops. Soil Sci. 101(4):267-282.

3. Beckett, P. H. T. and R. D. Davis, 1978. The additivity of the toxic effects of Cu, Ni and Zn in young barley. New Phytol. 81, 155-173.

4. Costescu, L. M. and T. C. Hutchinson, 1972. Ecological consequences of soil pollution by metallic dust from the Sudbury smelters. Proc. 18th Annual Technical Meeting of the Institute of Environmental Sciences, New York, May 1-4, 1972. pp. 540-545.

5. Cox, G. L., 1975. The effects of smelter emissions on the soils of the Sudbury area. M.Sc. Thesis, University of Guelph, Guelph, Ontario. 236 pp.

6. Davis, R. D., P. H. T. Beckett, and E. Wollan, 1978. Critical levels of twenty potentially toxic elements in young spring barley. Plant and Soil 49: 395-408.

7. Dreisinger, B. R., 1964. Sulphur dioxide levels in the Sudbury area and some effects of the gas on vegetation in 1963. Ontario Department of Mines, Sudbury, Ontario. 33 pp.

8. Dreisinger, B. R., 1970. Monitoring atmospheric sulphur dioxide and correlating its effects on crops and forests in the Sudbury area. In Proc. Conference on Impact of Air Pollution on Vegetation, Toronto. 23 pp.

9. Gorham, E., 1960. Some effects of smelter pollution northeast of Falconbridge, Ontario. Can. J. Bot. 38: 307-312.

10. Keller W. and J. R. Pitblado, 1986. Water quality changes in Sudbury area lakes: A comparison of synoptic surveys in 1974-1976 and 1981-83. Water, Air, and Soil Pollution 29: 285-296.

11. LeBlanc, F., 1972. The epiphytic vegetation of Populus balsamifera and its significance as an air pollution indicator in Sudbury, Ontario. Can. J. Bot. 50: 519-528.

12. Linzon, S. N., 1958. The Influence of Smelter Fumes on the Growth of White Pine in the Sudbury Region. Joint Publ., Ontario Dept. Lands and Forests, Ontario Dept. Mines, Toronto. 45 pp.

13. Linzon, S. N., 1971. Economic effects of sulphur dioxide on forest growth. J. Air Pollut. Control Assoc. 21:81-86.

14. Linzon, S. N., R. G. Pearson, J. A. Donnan and F. N. Durham, 1984. Ozone Effects on Crops in Ontario and Related Monetary Values. Ontario Ministry of the Environment, Toronto, ARB-13-84-Phyto. 60 pp.

15. McIlveen, W. D. and D. Balsillie, 1978. Air Quality Assessment Studies in the Sudbury Area - Volume 2. Effects of Sulphur Dioxide and Heavy Metals on Vegetation and Soil (1970-1977). Ontario Ministry of the Environment, Northeastern Region, Sudbury, Ontario. 105 pp.

16. McIlveen, W. D. and J. J. Negusanti, 1984. Marginal Chlorosis of White Birch in the Sudbury Area, 1978-1983. Progress Report No. 1. Ontario Ministry of the Environment, Northeastern Region, Sudbury. 70 pp.

17. McIlveen, W. D. and J. J. Negusanti, 1984. Report on the Investigation of Air Contaminant Injury to Vegetation at Rayside, Ontario, Conducted on August 8, 1984. Ontario Ministry of the Environment, Northeastern Region, Sudbury. 20 pp.

18. McGovern, P. C. and D., Balsillie, 1973. Sulphur Dioxide (1972) - Heavy Metal (1971) Levels and Vegetation Effects in the Sudbury Area. Air Management Branch, Ontario Ministry of the Environment, Sudbury, Ontario. 50 pp.

19. McGovern, P. C. and D., Balsillie, 1975. Effects of Sulphur Dioxide and Heavy Metals on Vegetation in the Sudbury Area (1974). Ontario Ministry of the Environment, Northeastern Region, Sudbury, Ontario. 33 pp.

20. Ontario Ministry of the Environment, 1983. Field Investigation Manual. Toronto.

21. Potvin, R. R. and D. Balsillie, 1976. Air Quality Monitoring Report for the Sudbury Area 1975. Ontario Ministry of the Environment, Northeastern Region, Sudbury, Ontario. 88 pp.

22. Potvin, R. R. and D. Balsillie, 1978. Air Quality Assessment Studies in the Sudbury Area - Volume 1. Air Quality Monitoring for the Sudbury Area (1976-1977). Ontario Ministry of the Environment, Northeastern Region, Sudbury, Ontario. 23 pp.

23. Spires, A. and W. D. McIlveen, 1985. Investigation of Metal Toxicity to Grass in the Copper Cliff Area, 1982-1984. Ontario Ministry of the Environment, Sudbury, NER-AQTM-31-85. 20 pp.

24. Tebbins, B. D. and D. H. Hutchinson, 1961. Application of air quality standards to a community problem. Journal of the Air Pollution Control Association. 11: 53-56.

25. Vegetation Enhancement Technical Advisors Committee, 1985. Land Reclamation Program, Regional Municipality of Sudbury, 1978-1983, Regional Municipality of Sudbury. 65 pp.

26. Ontario Ministry of the Environment, 1982. Sudbury Environmental Study Synopsis, 1973-1980. Ontario Ministry of the Environment Acidic Precipitation in Ontario Study Coordination Office, Toronto. 119 pp.

27. Ozvacic, V., 1982. Emissions of Sulphur Oxides, Particulates and Trace Elements in the Sudbury Basin. Air Resources Branch, Report No. ARB-ERTD-09-82. 69 pp.

28. Ozvacic, V. and J. McDonald, 1982. Sulphur Dioxide, Sulfuric Acid, Particulate and Particle Size Determinations at Falconbridge Smelter Stack, August, 1979. Air Resources Branch Report No. ARB-TOA40-80. pp. 49.

XIV. APPENDIX

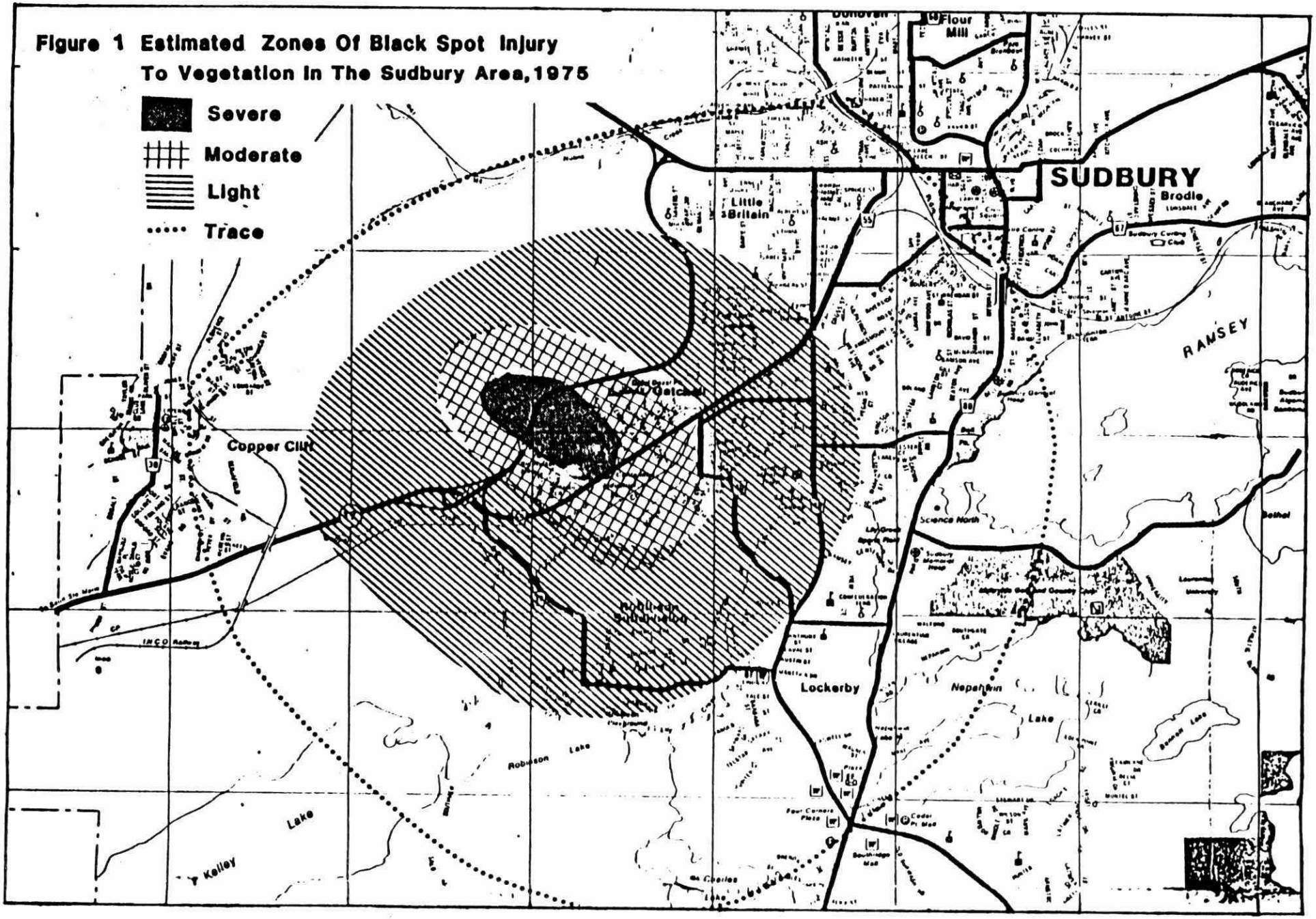
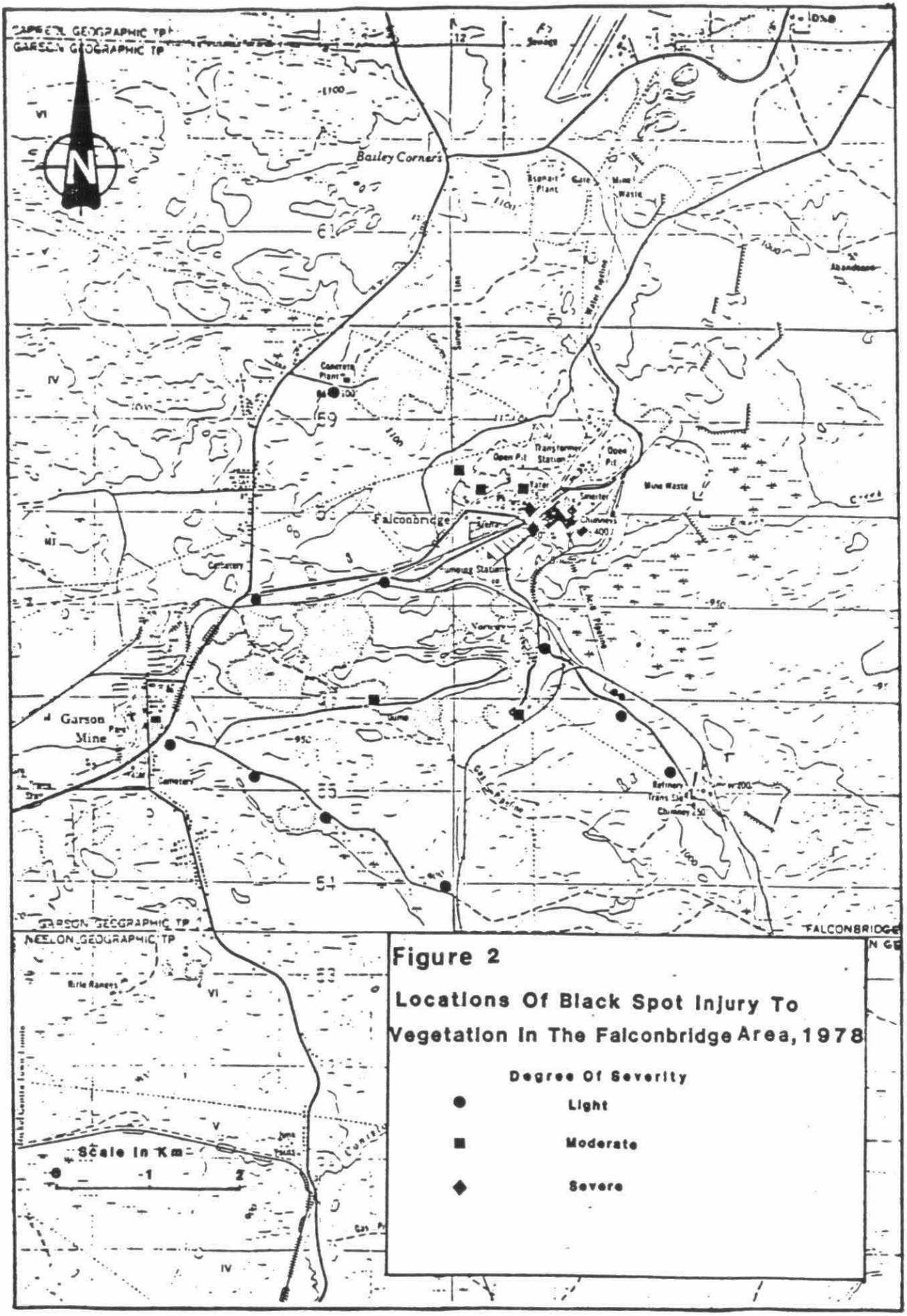


Figure 1 Estimated Zones Of Black Spot Injury
To Vegetation In The Sudbury Area, 1975
Severe
Moderate
Light
Trace
SUDBURY
Flour Mill
Little Britain
Brodie
RAMSEY
Copper Cliff
Garson
Science North
Lockerby
Nepahwin
Lake
Robinson
Lake
Kelley
Lake


GARSON GEOGRAPHIC TP
Bailey Corners
Falconbridge
Garson Mine
FALCONBRIDGE
NEELON GEOGRAPHIC TP
Scale in Km
Figure 2
Locations Of Black Spot Injury To Vegetation In The Falconbridge Area, 1978
Degree Of Severity
Light
Moderate
Severe

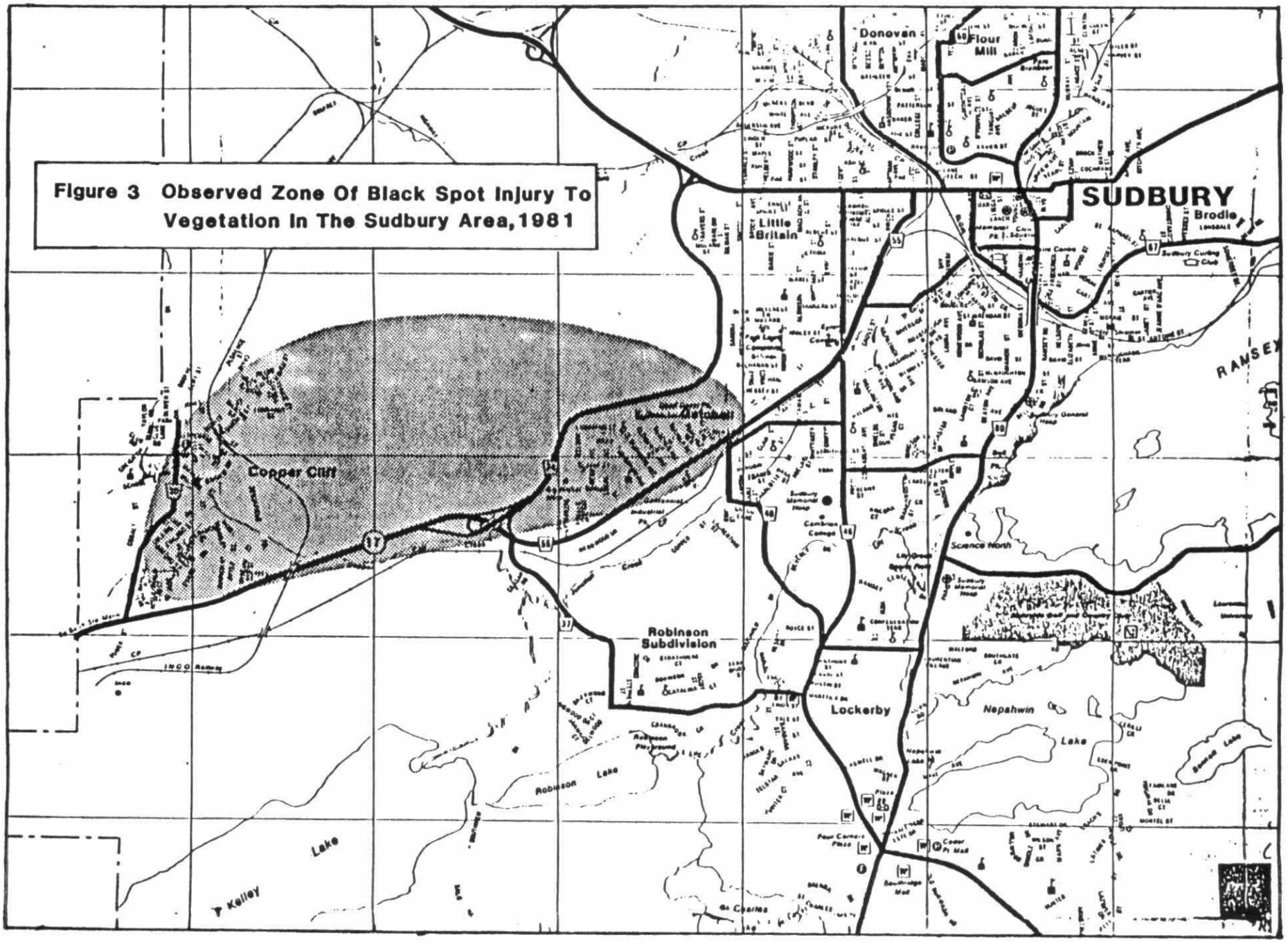


Figure 3 Observed Zone Of Black Spot Injury To Vegetation In The Sudbury Area, 1981
Donovan
Flour Mill
SUDBURY
Brodie
Little Britain
Copper Cliff
Robinson Subdivision
Lockerby
Science North
Nepahwin Lake
Robinson Lake
Lake
RAMSEY

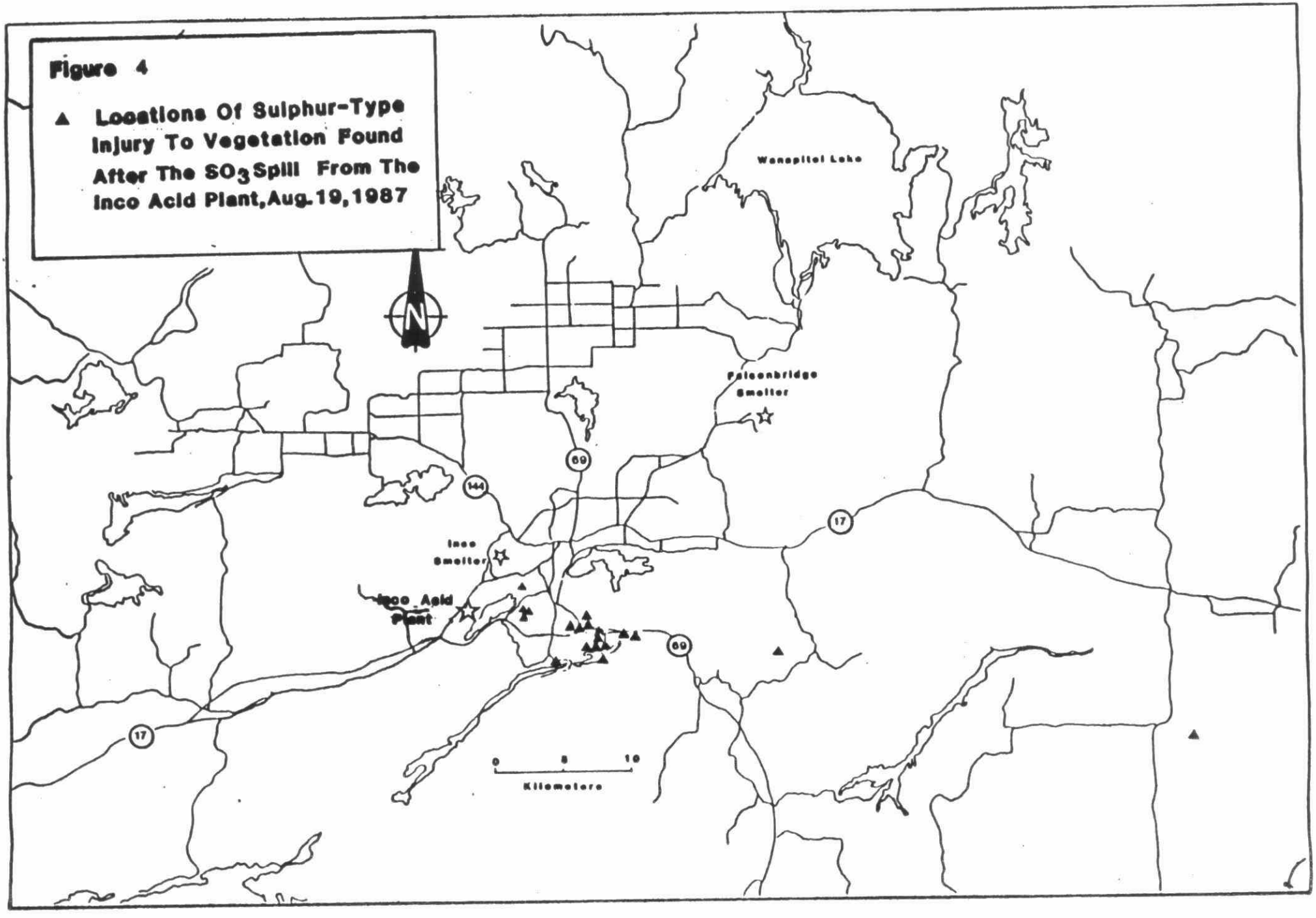


Figure 4
▲ Locations Of Sulphur-Type Injury To Vegetation Found After The SO_3 Spill From The Inco Acid Plant, Aug. 19, 1987
N
Wanapitei Lake
Falconbridge Smelter
Inco Smelter
Inco Acid Plant
69
144
17
0 5 10
Kilometers

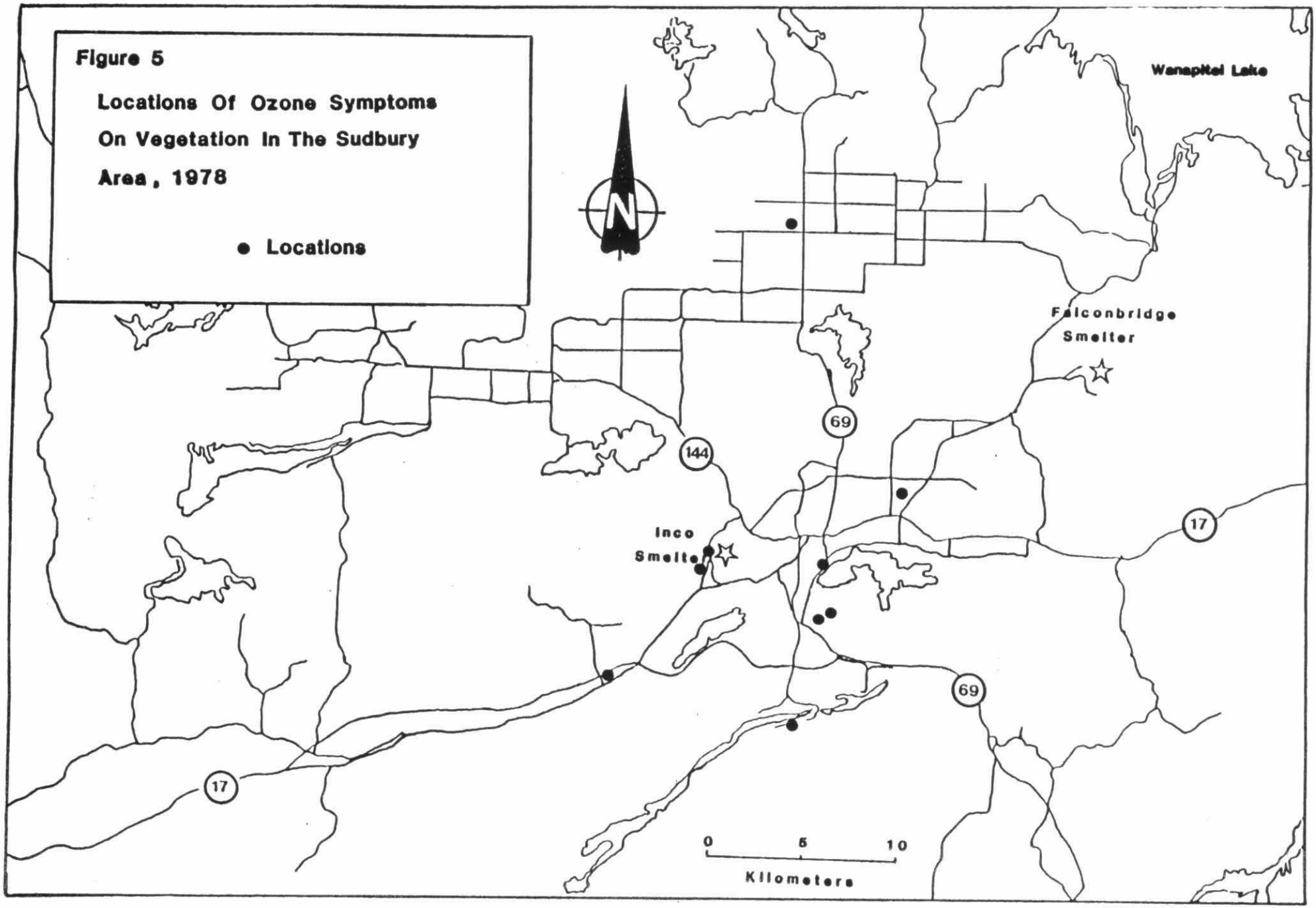


Figure 5
Locations Of Ozone Symptoms On Vegetation In The Sudbury Area, 1978
• Locations
N
Wanapitei Lake
Falconbridge Smelter
Inco Smelter
69
144
17
69
17
0
5
10
Kilometers

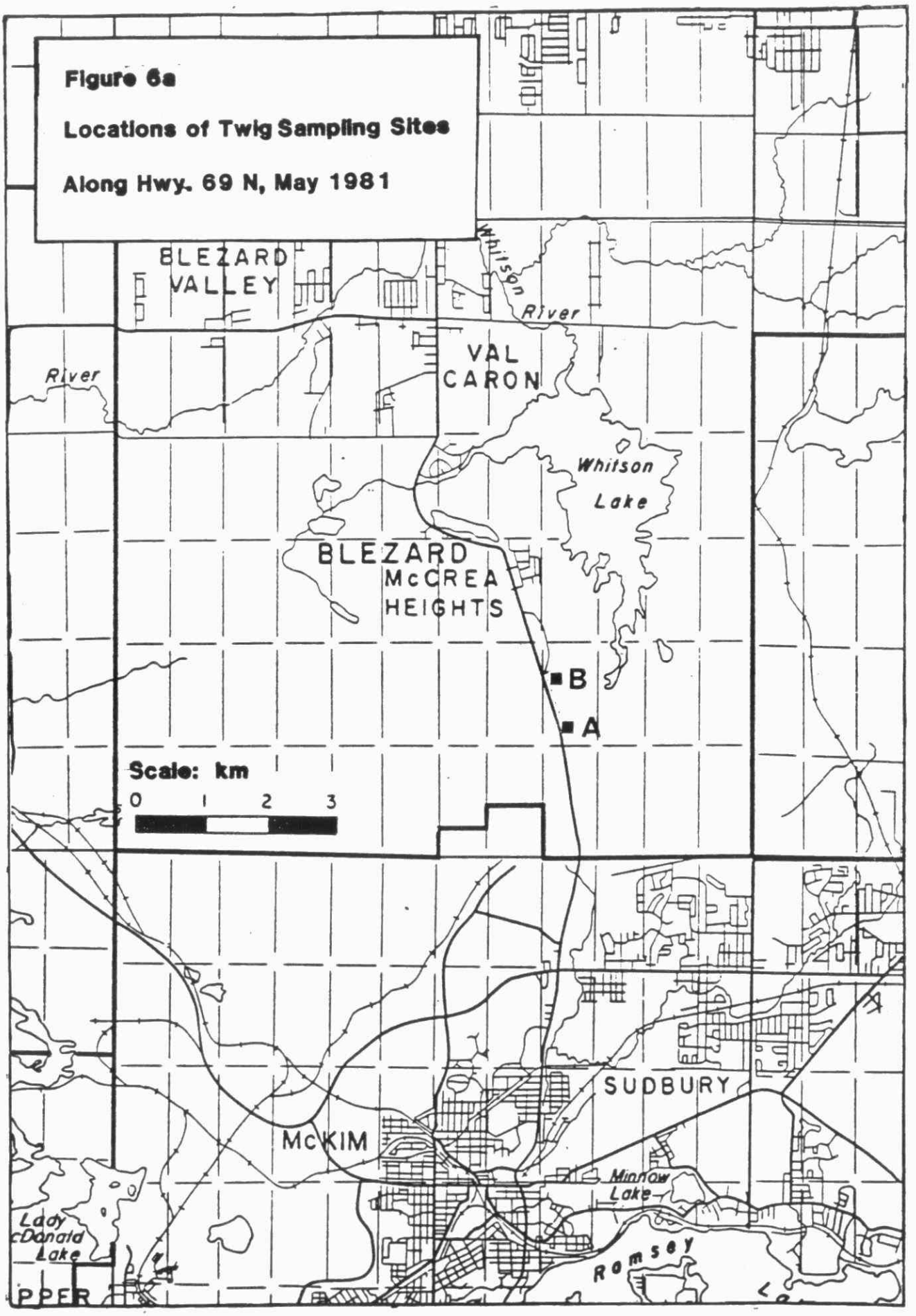
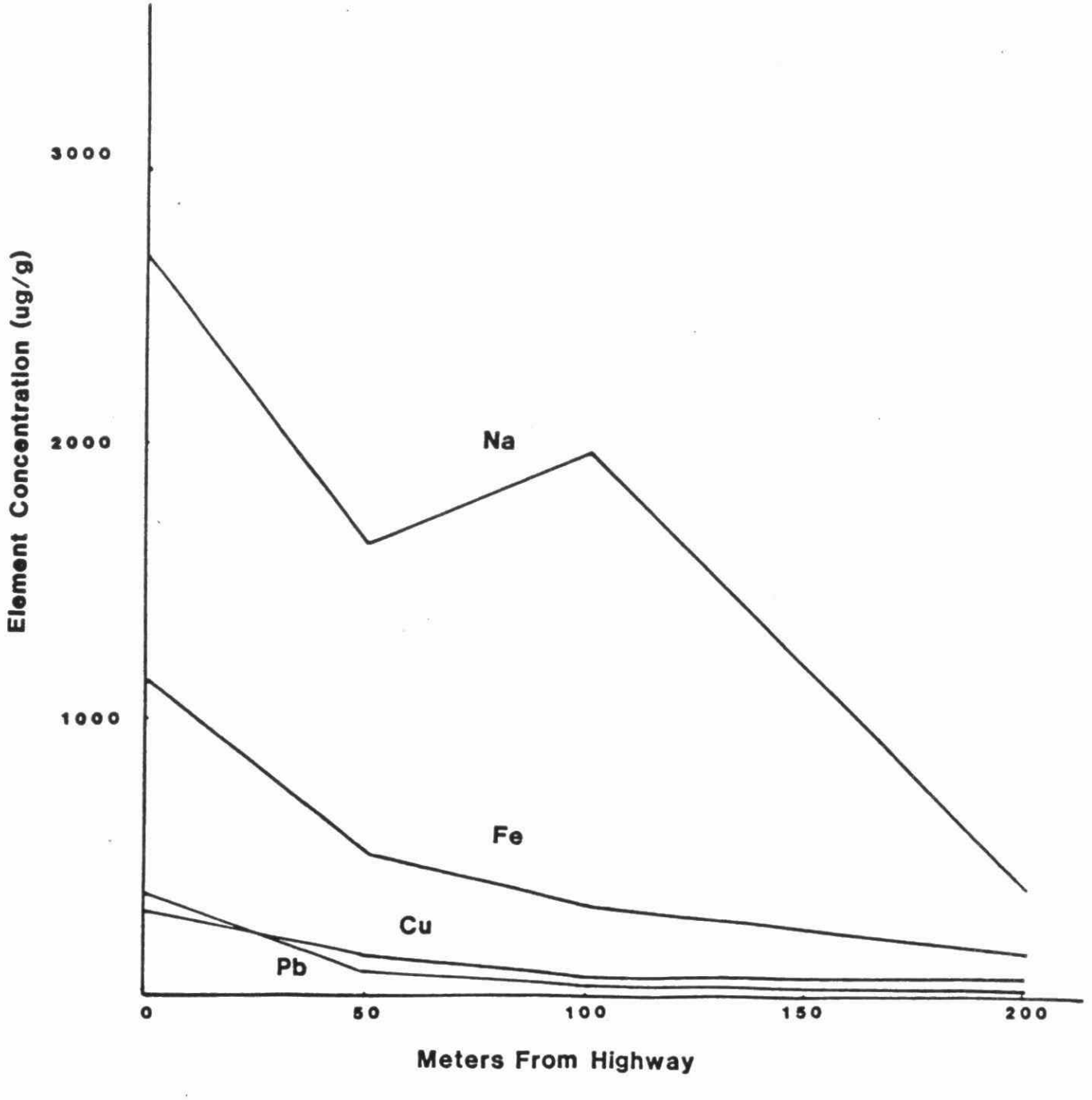


Figure 6a
Locations of Twig Sampling Sites
Along Hwy. 69 N, May 1981
BLEZARD VALLEY
Whitson River
River
VAL CARON
Whitson Lake
BLEZARD
McCREA HEIGHTS
B
A
Scale: km
0 1 2 3
SUDBURY
McKIM
Minnow Lake
Lady McDonald Lake
Ramsey

Figure 6b

Concentration Of Various Elements In White Birch Twigs At Site A Versus Distance From Highway 69, 1981



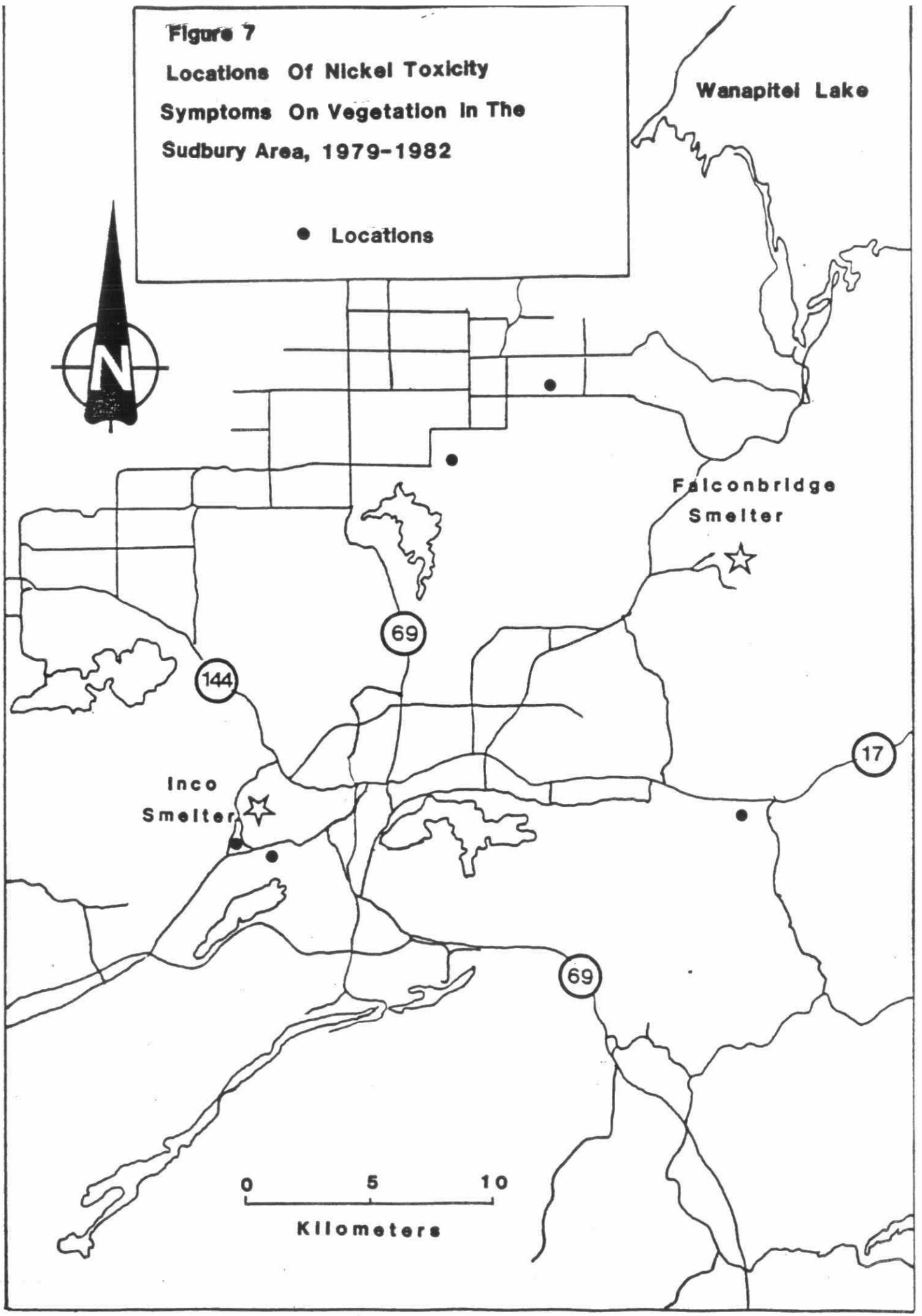
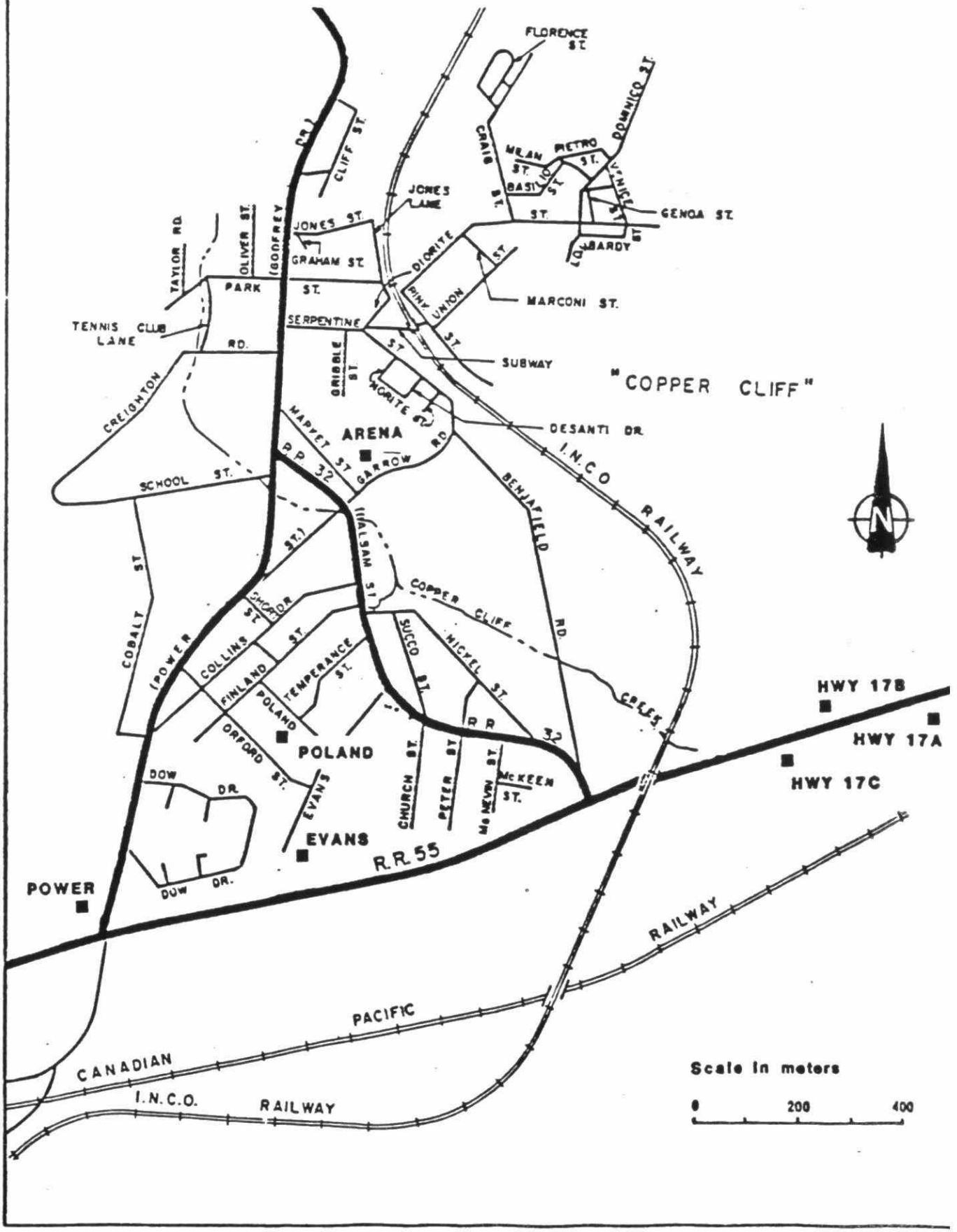


Figure 7
Locations Of Nickel Toxicity Symptoms On Vegetation In The Sudbury Area, 1979-1982
Locations
N
Wanapitei Lake
Falconbridge Smelter
Inco Smelter
69
144
17
69
0
5
10
Kilometers

Figure 8

Sampling Locations Of Chlorotic Grass And Soil In Copper Cliff



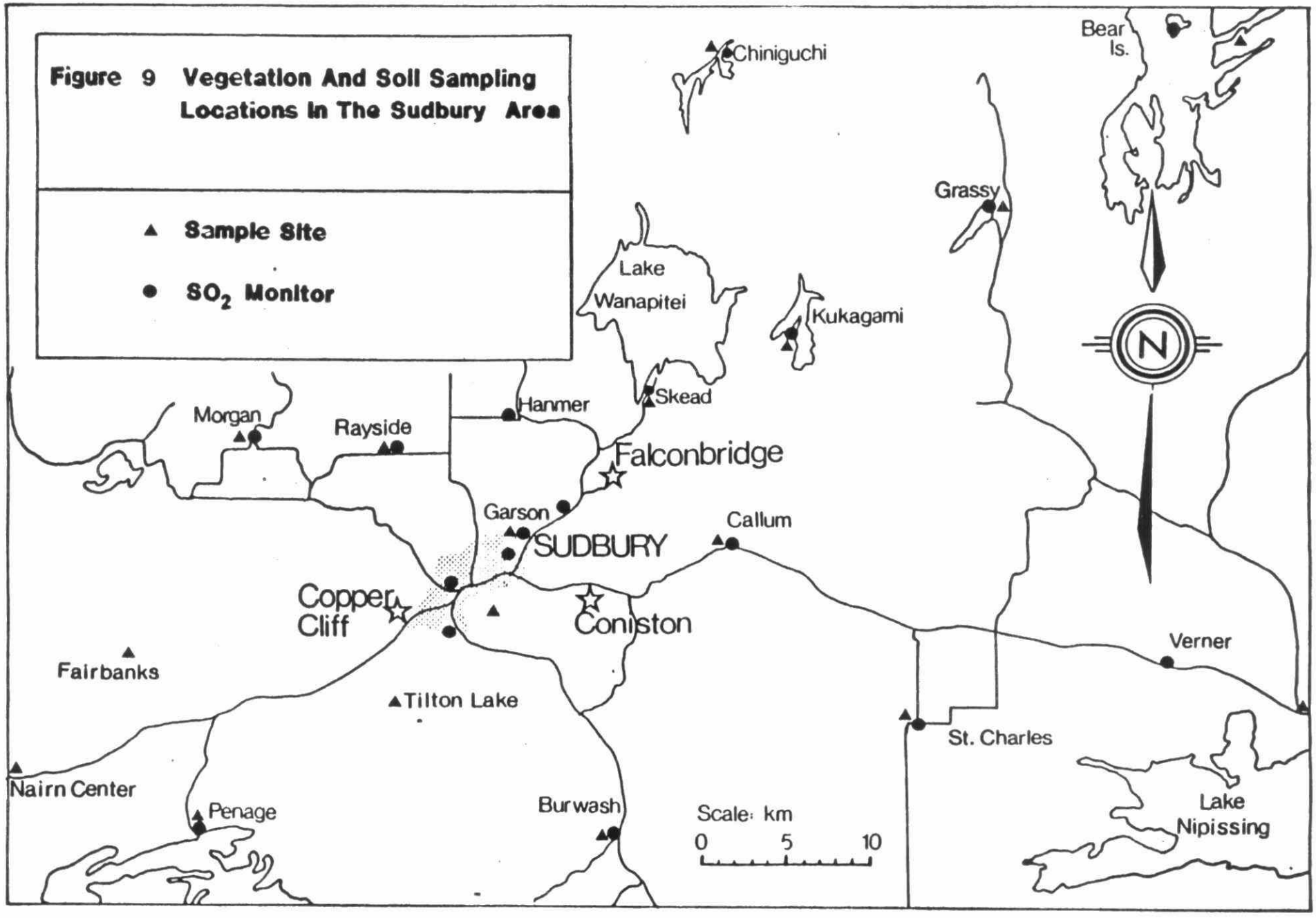


Figure 9 Vegetation And Soil Sampling Locations In The Sudbury Area
Sample Site
SO_2 Monitor
Chiniguchi
Bear Is.
Grassy
Lake Wanapitei
Kukagami
N
Skead
Hanmer
Morgan
Rayside
Falconbridge
Garson
SUDBURY
Callum
Copper Cliff
Coniston
Verner
Fairbanks
Tilton Lake
St. Charles
Nairn Center
Penage
Burwash
Lake Nipissing
Scale: km
0 5 10

Figure 10

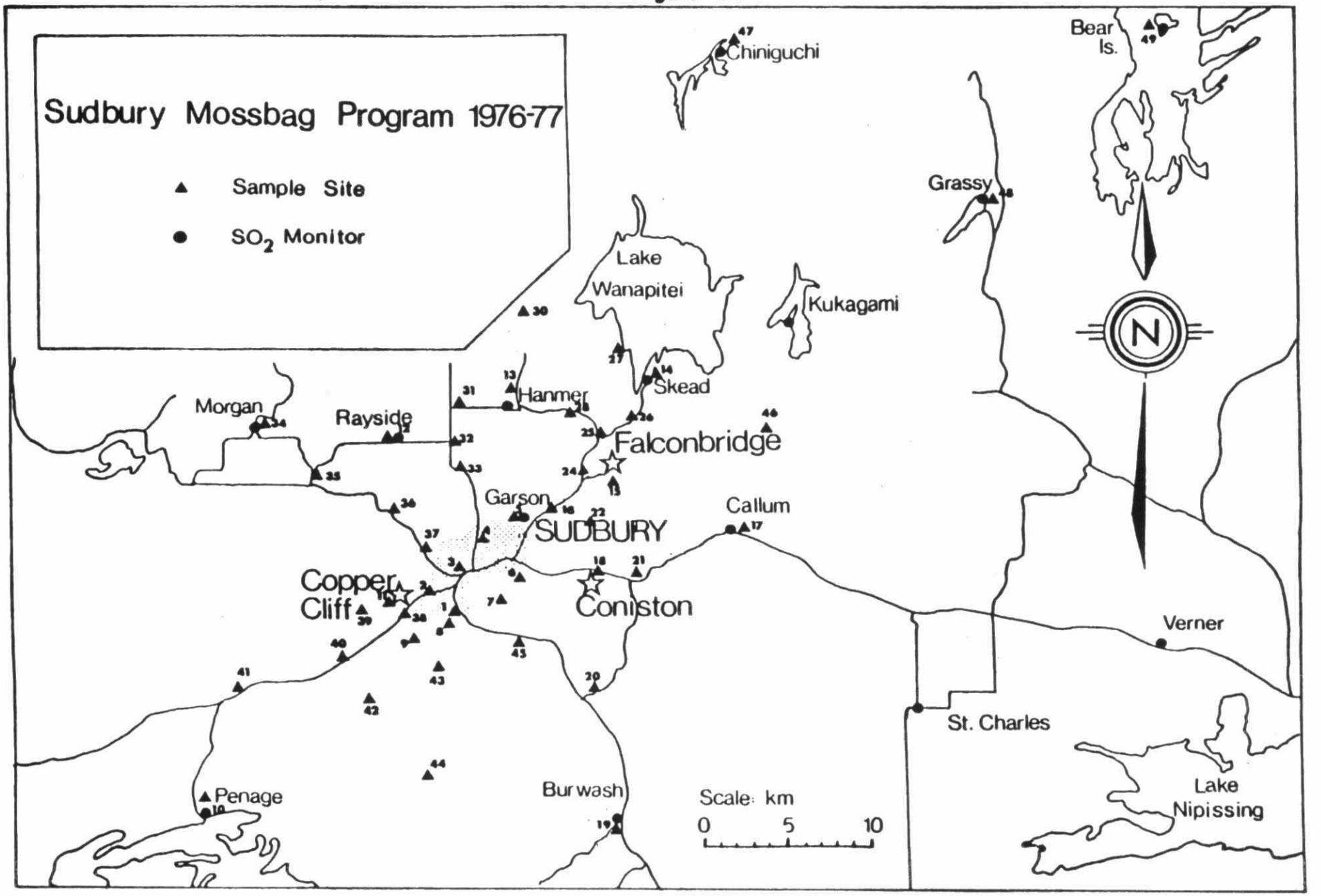

Sudbury Mossbag Program 1976-77
Sample Site
SO_2 Monitor
Chiniguchi
Bear Is.
Grassy
Lake Wanapitei
Kukagami
N
Morgan
Rayside
Hanmer
Skead
Falconbridge
Garson
SUDBURY
Callum
Copper Cliff
Coniston
Verner
St. Charles
Lake Nipissing
Penage
Burwash
Scale: km
0 5 10

FIGURE 11

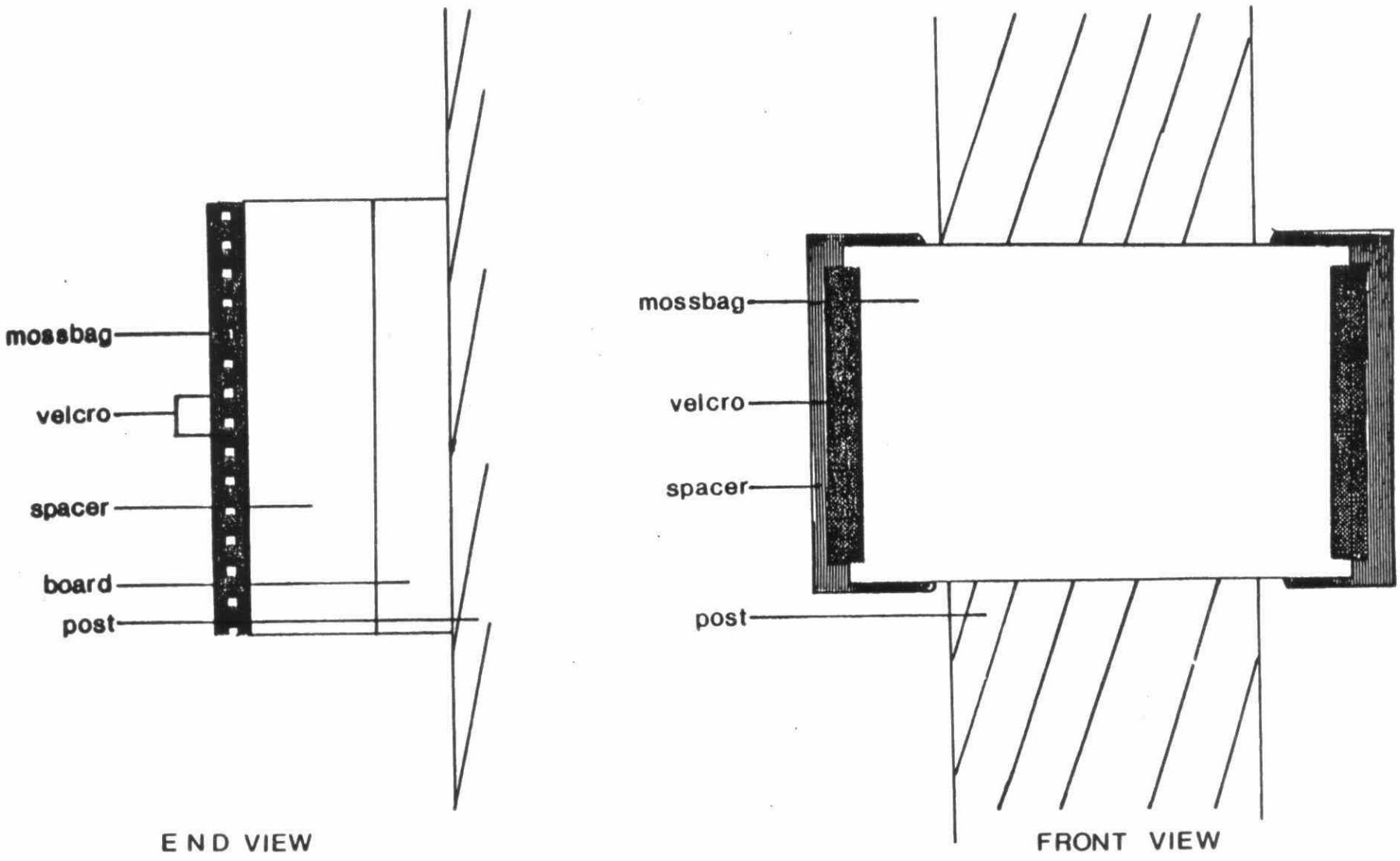


DIAGRAM OF CONSTRUCTION OF MOSSBAG MONITOR

FIGURE 12

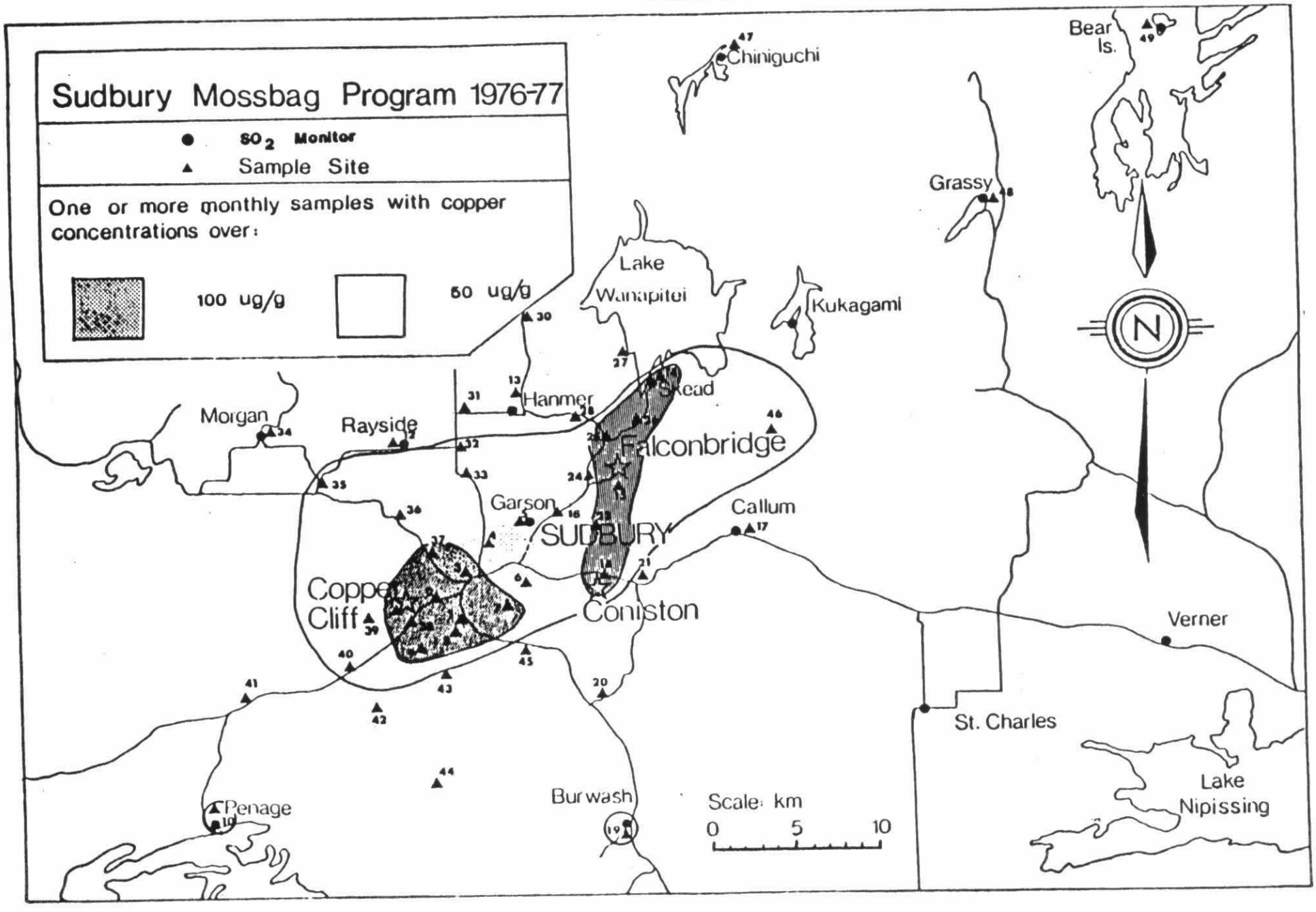

Sudbury Mossbag Program 1976-77
SO_2 Monitor
Sample Site
One or more monthly samples with copper concentrations over:
100 ug/g
60 ug/g
Chiniguchi
Bear Is.
Grassy
Lake Wanapitei
Kukagami
N
Morgan
Rayside
Hanmer
Skead
Falconbridge
Garson
SUDBURY
Callum
Copper Cliff
Coniston
Verner
St. Charles
Lake Nipissing
Penage
Burwash
Scale: km
0 5 10

FIGURE 13

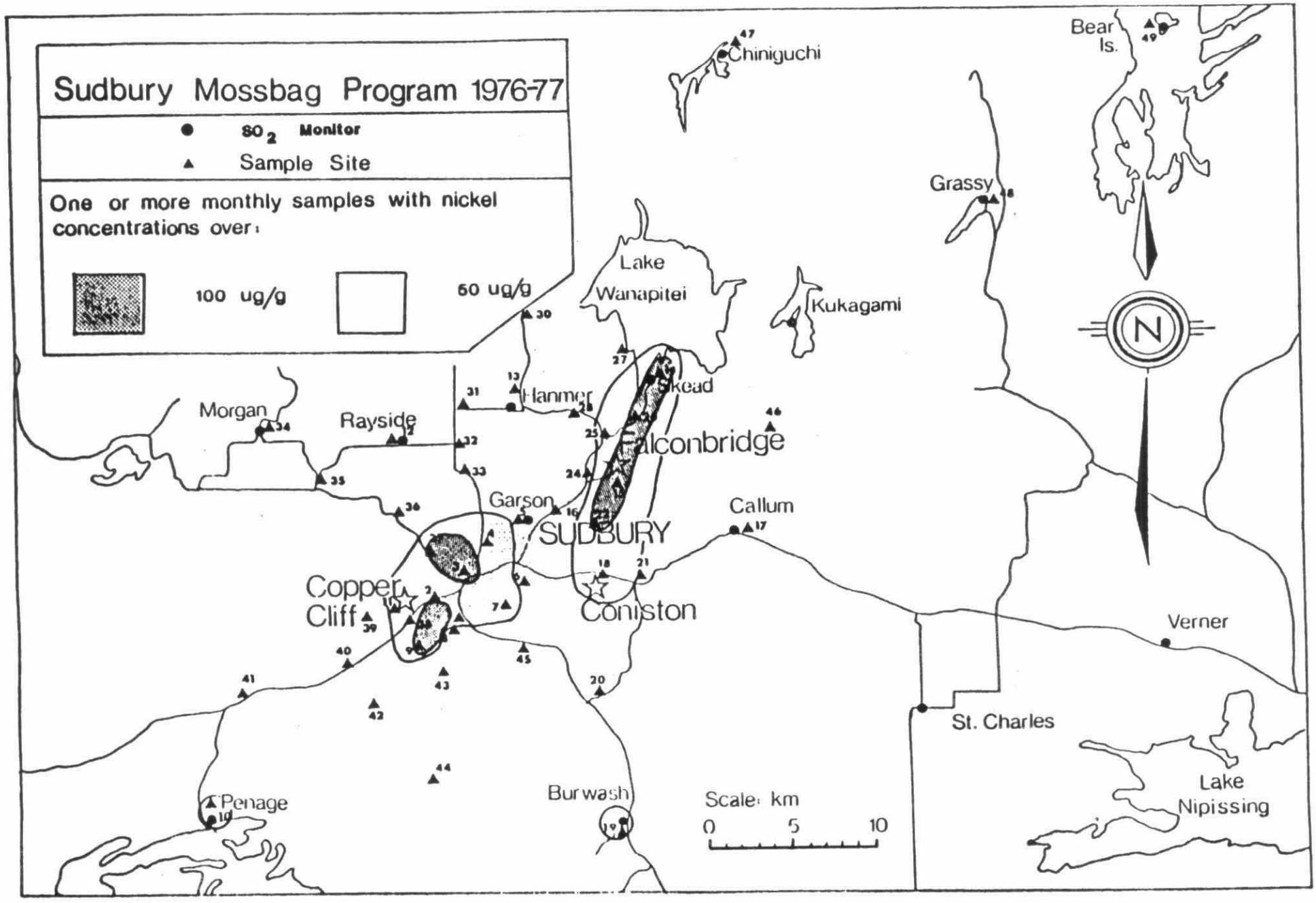

Sudbury Mossbag Program 1976-77
SO_2 Monitor
Sample Site
One or more monthly samples with nickel concentrations over:
100 ug/g
60 ug/g
Chiniguchi
Bear Is.
Grassy
Lake Wanapitei
Kukagami
N
Morgan
Rayside
Hanmer
Skead
Falconbridge
Garson
SUDBURY
Callum
Copper Cliff
Coniston
Verner
St. Charles
Penage
Burwash
Lake Nipissing
Scale: km
0 5 10

FIGURE 14

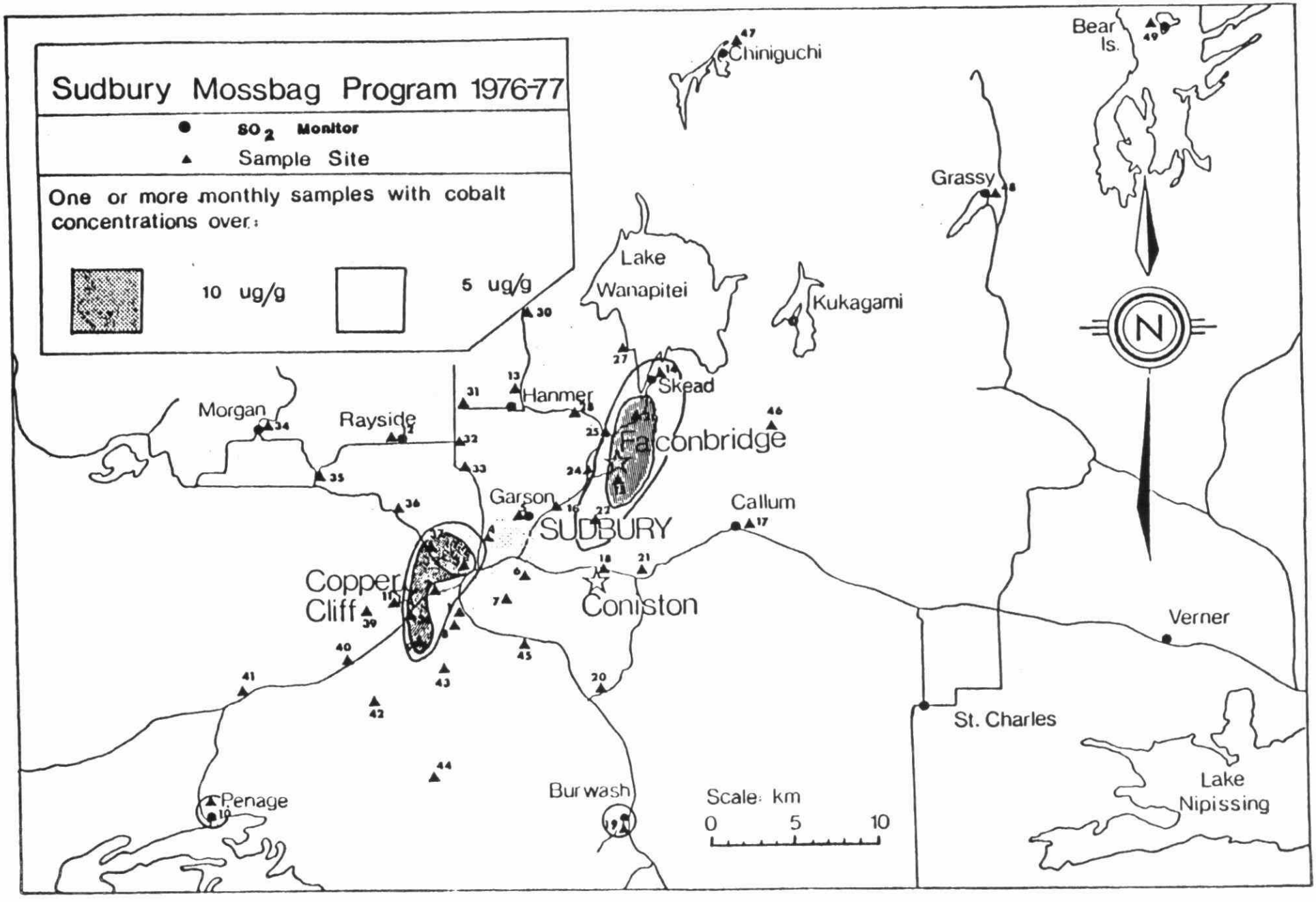

Sudbury Mossbag Program 1976-77
SO2 Monitor
Sample Site
One or more monthly samples with cobalt concentrations over:
10 ug/g
5 ug/g
Chiniguchi
Bear Is.
Grassy
Lake Wanapitei
Kukagami
N
Skead
Hanmer
Morgan
Rayside
Falconbridge
Garson
SUDBURY
Callum
Copper Cliff
Coniston
Verner
St. Charles
Lake Nipissing
Penage
Burwash
Scale: km
0 5 10

FIGURE 15

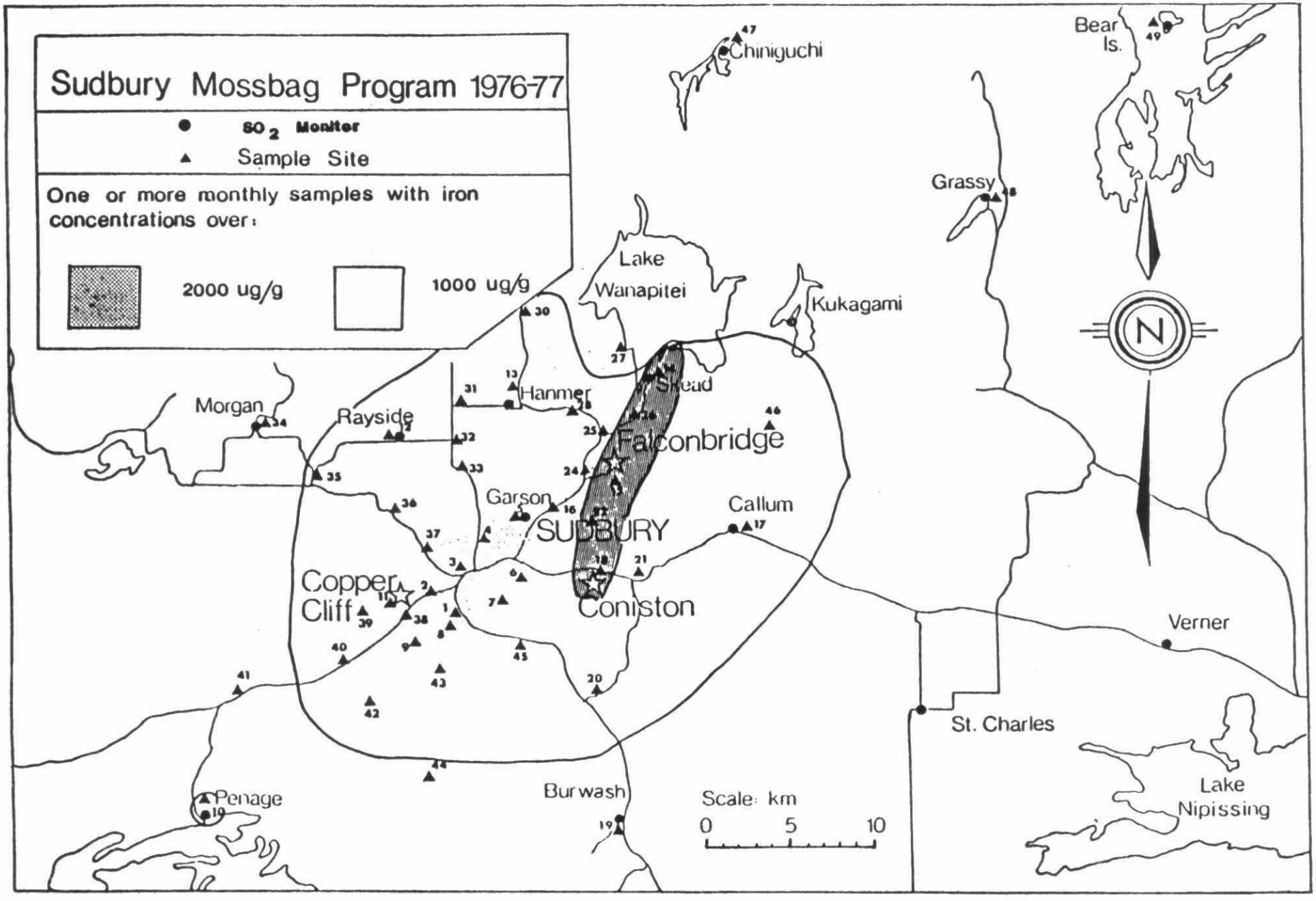

Sudbury Mossbag Program 1976-77
SO_2 Monitor
Sample Site
One or more monthly samples with iron concentrations over:
2000 ug/g
1000 ug/g
Chiniguchi
Bear Is.
Grassy
Lake Wanapitei
Kukagami
N
Morgan
Rayside
Hanmer
Skead
Falconbridge
Garson
SUDBURY
Callum
Copper Cliff
Coniston
Verner
St. Charles
Lake Nipissing
Penage
Burwash
Scale: km
0 5 10

FIGURE 16

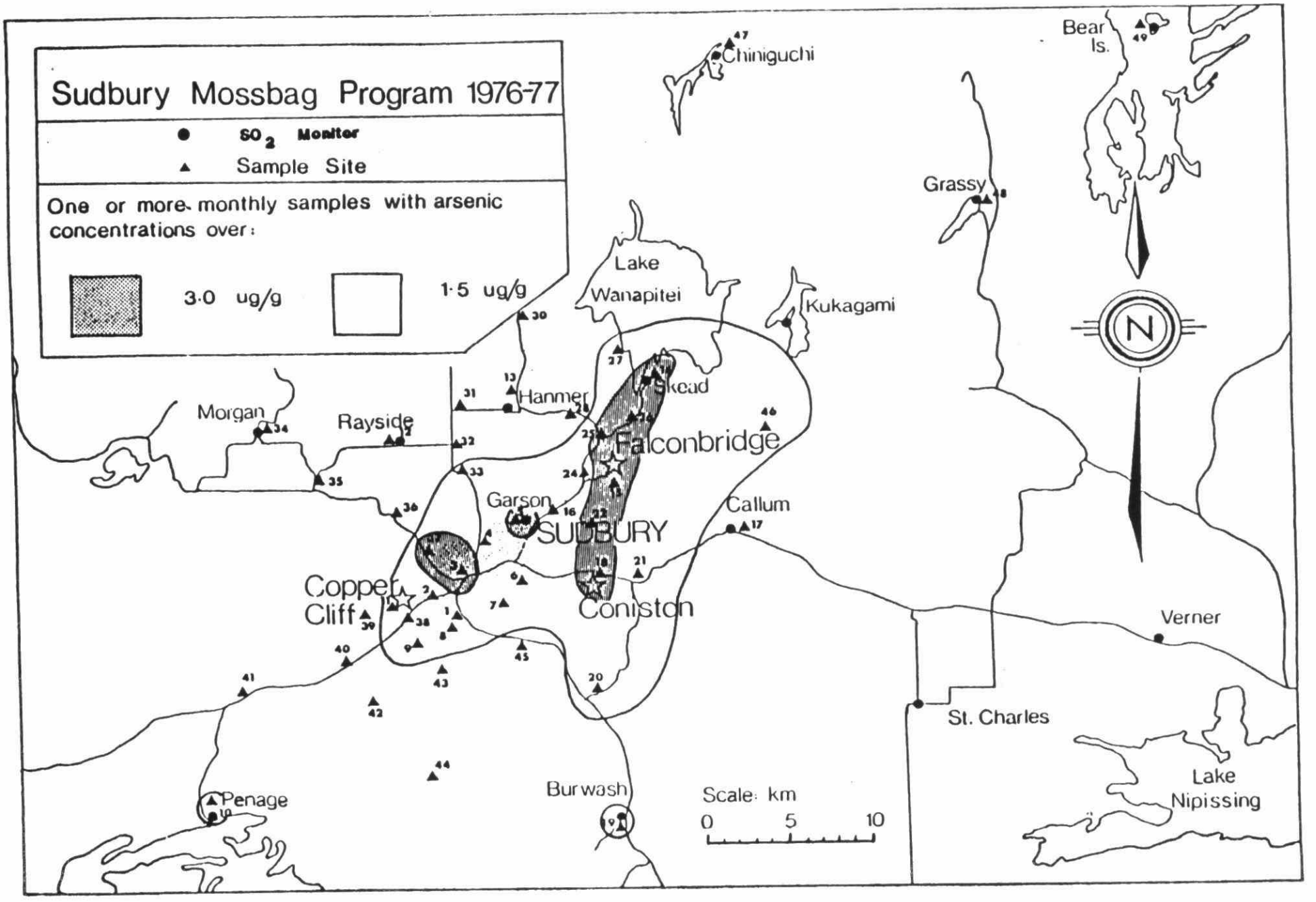

Sudbury Mossbag Program 1976-77
SO_2 Monitor
Sample Site
One or more monthly samples with arsenic concentrations over:
3.0 ug/g
1.5 ug/g
Chiniguchi
Bear Is.
Grassy
Lake Wanapitei
Kukagami
N
Hanmer
Skead
Morgan
Rayside
Falconbridge
Garson
SUDBURY
Callum
Copper Cliff
Coniston
Verner
St. Charles
Lake Nipissing
Penage
Burwash
Scale: km
0 5 10

FIGURE 17

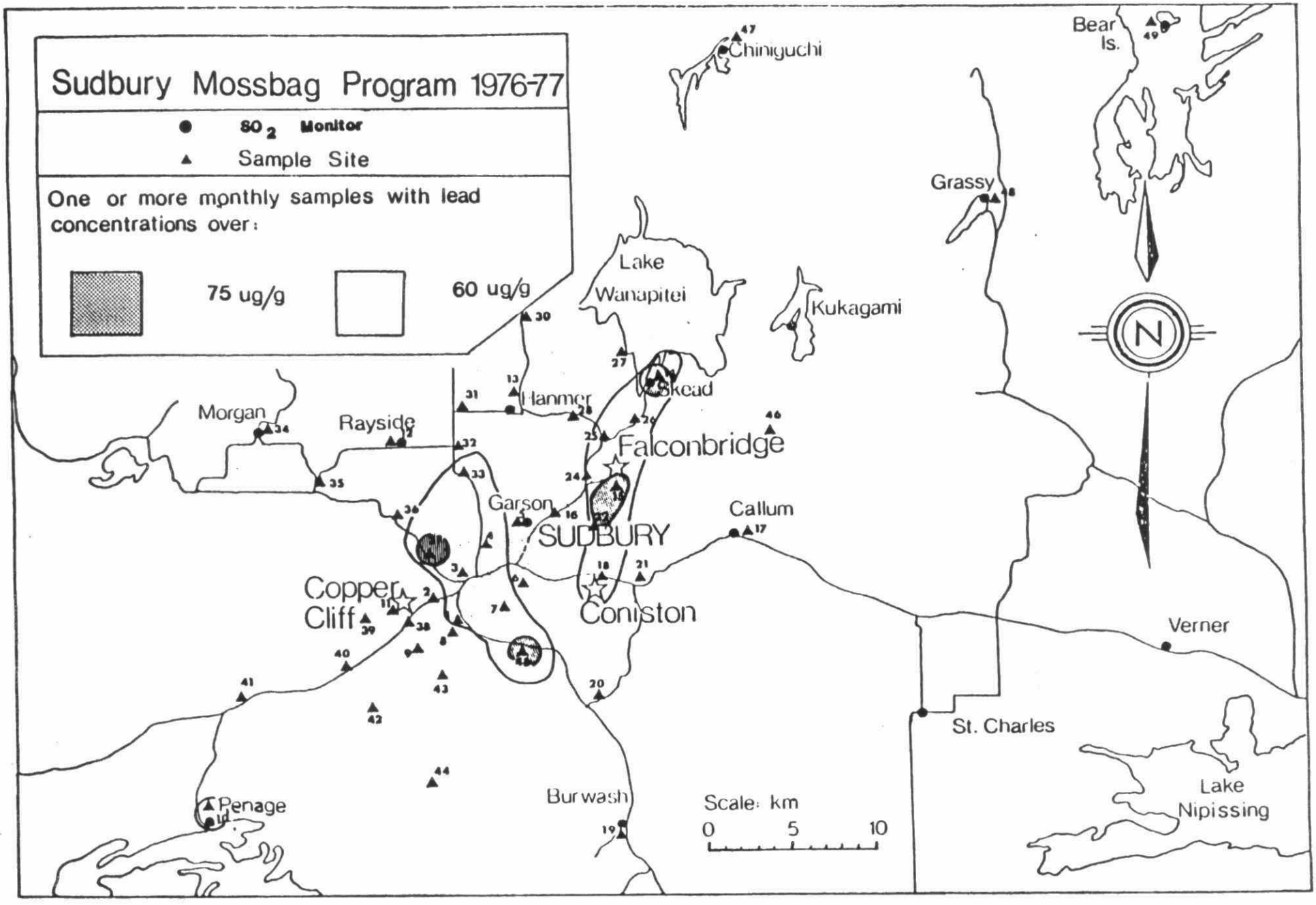

Sudbury Mossbag Program 1976-77
SO_2 Monitor
Sample Site
One or more monthly samples with lead concentrations over:
75 ug/g
60 ug/g
Chiniguchi
Bear Is.
Grassy
Lake Wanapitei
Kukagami
N
Skead
Hanmer
Morgan
Rayside
Falconbridge
Garson
SUDBURY
Callum
Copper Cliff
Coniston
Verner
St. Charles
Lake Nipissing
Penage
Burwash
Scale: km
0 5 10

TABLE 1

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1978

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings					Max. 1 Hr. Conc. (ppm)	Date
		0.0-0.04	.05-.25	.25+	.50+	1.0+		
Ash St. (Sudbury)	184	4136	213	10	1	0	.41	September 8
New Sudbury	184	4167	174	16	0	0	.44	July 1
Coniston	180	4122	152	16	2	0	.91	September 8
Lockerby	173	4013	91	16	7	0	.75	May 22
Lake Penage	175	4143	36	0	0	0	.19	May 17
Burwash	180	4244	50	1	0	0	.26	May 22
Callum	175	4106	62	3	0	0	.34	August 31
Skead	184	4048	260	55	5	0	.63	May 24
Hanmer	168	3903	144	11	1	0	.55	May 24
Rayside	172	4106	26	4	2	0	.75	May 30
Falconbridge Road	175	3929	173	14	0	0	.45	June 15
Morgan	184	4384	18	0	0	0	.18	June 19
St. Charles	180	4298	26	0	0	0	.16	June 2
Laurentian Hospital	146*	3512	17	0	0	0	.16	June 24
Verner	182	4265	5	3	0	0	.33	September 8
Chiniguchi Lake	132**	3143	78	1	0	0	.25	May 24
Lake Temagami	143**	3411	20	0	0	0	.16	September 4
Total	2917	67930	1545	150	18	0		

Total Hours: 69643

* operative days during June - Sept.
** operative days during June - Oct.

TABLE 2

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1979

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings					Max. 1 Hr. Conc. (ppm)	Date
		0.0-0.04	.05-.25	.25+	.50+	1.0+		
Ash St. (Sudbury)	172	3904	226	8	0	0	.26	June 28
New Sudbury	184	4116	211	15	2	0	.76	July 21
Coniston	182	4145	151	6	1	0	.52	October 4
Lockerby	165	3808	101	8	1	0	.43	July 18
Lake Penage	182	4313	32	0	0	0	.19	Sept. 3
Burwash	180	4167	63	2	0	0	.29	August 30
Callum	181	4203	63	1	0	0	.32	Sept. 30
Skead	183	4005	314	38	7	0	.59	Sept. 1
Hanmer	147	3390	112	5	0	0	.49	July 24
Rayside	181	4206	42	6	1	0	.57	Oct. 18
Falconbridge Road	184	4064	170	24	3	0	.61	Aug. 28
Morgan	184	4372	24	0	0	0	.22	Sept. 11
St. Charles	176	4128	18	0	0	0	.11	Aug. 14
Laurentian Hospital	110**	2600	16	0	0	0	.16	Sept. 16
Verner	153	3680	2	0	0	0	.11	May 12
Chiniguchi Lake	133*	3145	41	0	0	0	.21	Oct. 11
Lake Temagami	133*	3151	28	0	0	0	.22	Sept. 16
Total	2830	65397	1614	113	15	0		

Total Hours: 67139

* operative days during July - October
** operative days during June - October

TABLE 3

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1980

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings 0.0-0.04	.05-.25	.25+	.50+	1.0+	Max. 1 Hr. Conc. (ppm)	Date
Ash St. (Sudbury)	182	3972	366	16	1	0	.56	May 22
New Sudbury	174	3854	276	21	1	0	.51	July 3
Coniston	182	4034	246	23	2	1	1.07	Oct. 11
Lockerby	19*	585	28	1	0	0	.29	May 16
Lake Penage	172	4136	34	0	0	0	.17	Oct. 2
Burwash	179	4136	122	3	0	0	.41	Oct. 29
Callum	182	4185	143	2	0	0	.36	Oct. 15
Skead	177	3872	288	40	2	0	.45	Aug. 24
Hanmer	184	4186	174	17	2	0	.53	Aug. 20
Rayside	181	4196	67	3	0	0	.32	June 7
Falconbridge Road	184	3986	259	26	2	0	.87	May 1
Morgan	7*	178	2	0	0	0	.05	May 5
St. Charles	162	3820	24	0	0	0	.17	Oct. 2
Laurentian Hospital	116**	2670	118	6	0	0	.39	Aug. 3
Verner	7*	177	0	0	0	0	.02	May 4
Chiniguchi Lake	118+	2764	63	0	0	0	.20	Sept. 1
Lake Temagami	162	3792	37	0	0	0	.12	May 23
Total	2388	54543	2247	158	10	1		

Total Hours: 56959

* operative days during May only
** operative days during July - October
\+ operative days during June - October

TABLE 4

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1981

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings					Max. 1 Hr. Conc. (ppm)	Date
		0.0-0.04	.05-.25	.25+	.50+	1.0+		
Happy Valley	184	4015	272	105	38	5	1.08	June 22
Ash St. (Sudbury)	182	3980	240	5	0	0	.28	June 21
New Sudbury	174	3860	198	12	0	0	.45	Aug. 26
Coniston	179	3941	196	10	2	0	.64	Aug. 9
Long Lake Road	179	4070	165	10	2	0	.57	Aug. 17
Lake Penage	129*	3038	64	6	0	0	.36	May 10
Burwash	159	3740	56	0	0	0	.24	Sept. 14
Callum	174	4025	78	2	0	0	.39	Oct. 24
Skead	184	4070	207	26	3	0	.56	Oct. 14
Hanmer	183	4230	124	9	0	0	.38	Oct. 30
Rayside	182	4254	68	0	0	0	.22	Oct. 12
Falconbridge Road	167	3829	170	6	0	0	.45	July 28
Laurentian Hospital	180	4175	112	8	1	0	.56	Oct. 16
St. Charles	183	4335	23	0	0	0	.20	Sept. 18
Chiniguchi Lake	107**	2558	50	0	0	0	.23	June 13
Lake Temagami	178	4189	25	0	0	0	.10	May 25
Total	2724	62309	2048	199	46	5		

Total Hours: 64607

* operative days during May - September
** operative days during June - October

TABLE 5

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1982

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings					Max. 1 Hr. Conc. (ppm)	Date
		0.0-0.04	.05-.25	.25+	.50+	1.0+		
Ash St. (Sudbury)	179	4156	82	1	0	0	.31	Sept. 23
New Sudbury	181	4185						
Coniston	182	4213	57	2	0	0	.38	May 20
Long Lake Road	30*	711	25	0	0	0	.13	May 9
Burwash	28*	680	13	0	0	0	.19	May 25
Callum	30*	711	6	0	0	0	.19	May 25
Skead	30*	646	61	7	0	0	.42	May 19
Hanmer	30*	694	29	0	0	0	.19	May 6
Rayside	30*	700	18	3	0	0	.31	May 10
Falconbridge Road	30*	649	56	11	2	0	.69	May 31
Mikkola	36**	860	28	1	0	0	.32	May 20
St. Charles	72***	1711	5	0	0	0	.06	May 4
Happy Valley	26*	552	57	20	5	0	.69	May 20
Laurentian Hospital	29*	685	22	0	0	0	.20	May 8
Lake Temagami	143+	3411	20	0	0	0	.10	May 7
Total	1056	24564	479	45	7	0		

Total Hours: 25095

* operative days during May only
** operative days during May - June
*** operative days during May - July
\+ operative days during May - September

TABLE 6

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1983

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings 0.0-0.04	.05-.25	.25+	.50+	1.0+	Max. 1 Hr. Conc. (ppm)	Date
Ash St. (Sudbury)	181	4027	245	13	1	0	.56	Aug. 5
New Sudbury	178	3972	199	14	0	0	.47	Aug. 8
Coniston	175	4027	135	8	0	0	.37	Aug. 18
Long Lake Road	179	4152	120	16	2	2	1.21	May 25
Burwash	124*	2932	37	1	0	0	.32	Aug. 28
Callum	170	3992	63	1	0	0	.44	Oct. 6
Skead	151*	3340	220	39	0	0	.39	Sept. 29
Hanmer	149*	3459	102	8	0	0	.41	Sept. 28
Rayside	180	4261	50	5	0	0	.30	Aug. 21
Falconbridge Road	141*	3134	186	19	5	0	.97	Aug. 27
Mikkola	140*	3298	56	9	1	0	.57	June 27
St. Charles	163	3866	20	0	0	0	.17	June 21
Happy Valley	discontinued, August 1982		--	--	--	--	--	--
Laurentian Hospital	144	3436	112	8	1	0	.56	Aug. 23
Lake Temagami	184	4355	27	0	0	0	.10	Aug. 29
Total	2259	52251	1572	141	10	2		

Total Hours: 53976

* operative days during June - October

TABLE 7

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1984

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings 0.0-0.04	.05-.25	.25+	.50+	1.0+	Max. 1 Hr. Conc. (ppm)	Date
Ash St. (Sudbury)	182	4067	237	11	1	0	.50	June 4
New Sudbury	181	3932	215	14	0	0	.47	Oct. 29
Coniston	177	3846	186	10	1	0	.50	May 1
Long Lake Road	172	3935	129	11	3	0	.79	Sept. 5
Burwash	171	3899	61	1	0	0	.33	May 26
Callum	172	3965	87	3	0	2	.36	Sept. 29
Skead	168	3681	282	22	3	0	1.00	July 15
Hanmer	160	3643	166	10	2	0	.90	Aug. 28
Rayside	168	3907	72	2	2	0	.85	Aug. 2
Falconbridge Road	164	3737	196	11	4	0	.92	June 6
Mikkola	166	3796	133	14	4	0	.65	Oct. 9
St. Charles	Discontinued, January 1984		--	--	--	--	--	
Laurentian Hospital	50*	1136	52	2	0	0	.34	June 20
Lake Temagami	173	3986	24	0	0	0	.10	Sept. 28
High Falls	29**	663	11	0	0	0	.20	Oct. 2
Science North	90***	2028	55	11	0	0	.45	Sept. 21
Total	2223	50221	1906	122	20	2		

Total Hours: 52271

* operative days during May - June
** operative days during October
*** operative days during August - October

TABLE 8

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1985

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings					Max. 1 Hr. Conc. (ppm)	Date
		0.0-0.04	.05-.25	.25+	.50+	1.0+		
Burwash	178	4199	80	0	0	0	.23	Oct. 28
Callum	162	3793	80	0	0	0	.21	May 13
Skead	183	4058	285	21	4	0	.62	Sept. 19
Hanmer	184	4220	133	12	0	0	.44	Aug. 4
Rayside	49*	1146	21	1	0	0	.30	June 6
Ash St. (Sudbury)	183	4121	243	30	1	0	.51	June 4
Coniston	181	4105	178	7	0	0	.34	June 2
Falconbridge Road	181	4113	233	13	0	0	.35	Oct. 14
Lake Temagami	53*	1242	3	0	0	0	.06	May 16
New Sudbury	184	4063	276	21	1	0	.66	Aug. 14
Long Lake Road	179	4168	112	18	2	0	.65	Sept. 13
Mikkola	175	4115	123	8	1	0	.80	Aug. 30
High Falls	87	2068	21	5	0	0	.38	Oct. 15
Science North	178	4068	177	21	2	0	.92	Oct. 11
Regional Road	84**	1968	38	4	0	0	.39	Aug. 12
Total	2241	51447	2003	161	11	0		

Total Hours: 53622

* operative days during May - June
** operative days during July - October

TABLE 9

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1986

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings					Max. 1 Hr. Conc. (ppm)	Date
		0.0-0.04	.05-.25	.25+	.50+	1.0+		
Skead	173	3919	201	20	1	0	.53	Oct. 25
Hanmer	180	4224	89	2	0	0	.20	Sept. 9
Ash St. (Sudbury)	166	3502	170	4	1	0	.46	May 28
Coniston	167	3531	127	3	0	0	.28	Sept. 7
Falconbridge Road	182	4161	207	14	3	0	.65	Oct. 24
New Sudbury	169	3536	172	13	0	0	.49	Oct. 1
Long Lake Road	184	4237	157	14	0	0	.49	Oct. 9
Mikkola	179	4111	150	23	1	0	.74	May 22
High Falls	1*	28	0	0	0	0	.02	May 1
Science North	177	4115	144	11	0	0	.46	Sept. 7
Regional Road	156	3655	70	2	0	0	.35	Oct. 10
Total	1734	39019	1487	106	6	0		

Total Hours: 40618

* operative days during May

TABLE 10

SUMMARY OF THE SO_2 MONITORING DATA FOR THE SUDBURY AREA FROM MAY TO OCTOBER 1987

Station	Operative Days (May to October)	Distribution of SO_2 Hourly Readings					Max. 1 Hr. Conc. (ppm)	Date
		0.0-0.04	.05-.25	.25+	.50+	1.0+		
Ash St. (Sudbury)	172	3882	254	15	2	0	.98	Aug. 27
Coniston	182	4179	111	11	1	0	.51	Aug. 27
Garson	182	4132	221	14	1	0	.61	Aug. 27
Hanmer	183	4221	143	12	1	0	.72	Aug. 12
Mikkola	148	3401	130	16	1	0	.65	June 20
New Sudbury	180	4062	188	30	3	0	.80	Aug. 27
Rayside	183	4318	55	10	2	0	.60	Aug. 9
Skead	156	3469	255	15	1	0	.41	May 14
Long Lake Road	178	4177	116	13	1	0	.69	May 5
Science North	182	4184	168	10	2	0	.70	Aug. 3
Total	1746	40025	1641	146	15	0		

Total Hours: 41827

TABLE 11

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1978 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Ash Street	0	(August 31)*	(72)
Lockerby	2	May 21	178
	-	July 11	105
Falconbridge	0	(June 15)	(65)
Skead	3	May 24	116
	-	June 7	110
	-	June 11	108
Chiniguchi Lake	0	(May 24)	(42)
Grassy Lake	0	(June 24)	(31)
Lake Temagami	0	(September 9)	(22)
Coniston	1	September 8	188
Callum	0	(August 31)	(58)
St. Charles	0	(July 4)	(23)
Verner	0	(September 8)	(58)
Burwash	0	(May 10)	(33)
Hanmer	0	(June 25)	(87)
Rayside	1	May 30	154
Morgan	0	(August 31)	(72)
Lake Penage	0	(May 10)	(33)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 12

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1979 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Ash Street	0	(July 7)*	(46)
Lockerby	0	(October 8)	(68)
Falconbridge	1	September 16	107
Skead	0	(September 9)	(79)
Chiniguchi Lake	0	(October 11)	(37)
Grassy Lake	0	(September 16)	(27)
Lake Temagami	0	(September 16)	(37)
Coniston	1	(October 4)	(87)
Callum	0	(June 22)	(43)
St. Charles	0	(September 21)	(21)
Verner	0	(May 12)	(12)
Burwash	0	(August 30)	(46)
Hanmer	0	(October 27)	(72)
Rayside	1	October 18	125
Morgan	0	(September 11)	(33)
Lake Penage	0	(September 3)	(33)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 13

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1980 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Ash Street	0	(August 19)*	(75)
Lockerby	0	(May 16)	(52)
Falconbridge	2	May 1	114
	-	July 26	104
Skead	0	(August 30)	(68)
Chiniguchi Lake	0	(September 1)	(27)
Lake Temagami	0	(May 23)	(27)
Coniston	2	October 11	151
	-	June 26	112
Callum	0	(October 15)	(60)
St. Charles	0	(October 2)	(20)
Verner	0	(May 6)	(3)
Burwash	0	(October 29)	(70)
Hanmer	1	June 5	108
Rayside	0	(June 7)	(68)
Lake Penage	0	(May 28)	(55)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 14

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1981 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Ash Street	0	(June 21)*	(57)
Falconbridge	0	(May 27)	(56)
Skead	0	(October 17)	(85)
Chiniguchi Lake	0	(June 13)	(36)
Lake Temagami	0	(May 25)	(19)
Coniston	0	(August 9)	(97)
Callum	0	(October 24)	(41)
St. Charles	0	(September 18)	(23)
Burwash	0	(September 14)	(41)
Hanmer	1	(October 30)	(61)
Rayside	0	(September 3)	(51)
Lake Penage	0	(May 10)	(94)
Long Lake Road	1	August 17	107
Happy Valley	8	May 5	133
		May 6	101
		June 22	187
		June 26	130
		August 24	119
		August 16	103
		September 5	189
		September 30	108
Laurentian Hospital	0	(October 16)	(83)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 15

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1982 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Ash Street	0	(May 15)*	(40)
Falconbridge	1	May 31	104
Skead	0	(May 19)	(75)
Lake Temagami	0	(May 7)	(26)
Coniston	0	(May 20)	(47)
Callum	0	(May 25)	(21)
St. Charles	0	(May 25)	(13)
Burwash	0	(May 8)	(39)
Hanmer	0	(May 29)	(44)
Rayside	0	(May 10)	(53)
Long Lake Road	0	(May 2)	(24)
Happy Valley	2	May 20	162
	-	May 9	116
Laurentian Hospital	0	(May 8)	(36)
Mikkola	0	(May 20)	(49)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 16

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1983 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Ash Street	0	(August 5)*	(87)
Falconbridge	2	August 27	109
		September 16	117
Skead	0	(August 24)	(71)
Lake Temagami	0	(August 8)	(15)
Coniston	0	(September 21)	(66)
Callum	0	(October 6)	(62)
St. Charles	0	(May 27)	(25)
Burwash	0	(August 28)	(50)
Hanmer	0	(September 28)	(74)
Rayside	0	(October 11)	(42)
Long Lake Road	1	May 25	214
Laurentian Hospital	0	(June 17)	(64)
Mikkola	1	June 27	114
New Sudbury	0	(September 8)	(79)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 17

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1984 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Ash Street	0	(September 6)*	(83)
Falconbridge Road	1	June 6	154
Skead	0	(July 10)	(74)
Lake Temagami	0	(September 28)	(16)
Coniston	0	(May 1)	(58)
Callum	0	(October 23)	(39)
Burwash	0	(May 26)	(50)
Hanmer	1	August 28	122
Rayside	1	August 2	130
Long Lake Road	1	September 5	114
Laurentian Hospital	0	(June 20)	(66)
Mikkola	1	(October 9)	113
Science North	0	(August 17)	(86)
New Sudbury	0	(October 29)	(98)
High Falls	0	(October 2)	(30)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 18

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1985 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Burwash	0	(October 10)*	(47)
Callum	0	(May 13)	(34)
Skead	0	(September 19)	(79)
Hanmer	0	(October 3)	(71)
Rayside	0	(June 6)	(50)
Ash Street	1	June 4	107
Coniston	0	(September 4)	(58)
Falconbridge Road	0	(September 24)	(71)
Lake Temagami	0	(May 16)	(11)
New Sudbury	0	(September 15)	(78)
Long Lake Road	1	June 12	118
Mikkola	1	August 30	126
High Falls	0	(May 14)	(51)
Science North	0	(October 11)	(97)
Regional Road	0	(September 23)	(64)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 19

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1986 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Skead	0	(October 25)*	(84)
Hanmer	0	(October 1)	(39)
Ash Street	0	(May 28)	(48)
Coniston	0	(October 19)	(40)
Falconbridge Road	0	(August 19)	(92)
New Sudbury	0	(August 15)	(83)
Long Lake Road	0	(August 24)	(98)
Mikkola	2	May 22	100
	-	August 18	103
High Falls	0	(May 1)	(2)
Science North	0	(September 7)	(96)
Regional Road	0	(October 10)	(55)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 20

Potentially Injurious Fumigations Recorded by
Sudbury Area Monitors During the 1987 Growing Season

Station	# P.I.F.	Date	Maximum Intensity
Ash Street	1	August 27	139
Coniston	0	(August 27)*	(92)
Garson	0	(August 27)	(91)
Hanmer	1	August 12	101
Mikkola	0	(May 10)	(91)
New Sudbury	1	August 27	140
Rayside	0	(August 9)	(90)
Skead	0	(May 14)	(80)
Long Lake Road	1	May 5	107
Science North	0	(August 3)	(81)

* Dates and intensity values in brackets indicate maximum seasonal fumigation intensities below 100 recorded at the SO_2 monitoring stations.

TABLE 21

Annual Growing Season Maximum Fumigation Intensities (P.I.F.)
Recorded at Sudbury Area SO_2 Monitors - 1970-1987

Station	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
Ash Street	-	-	-	-	177	74	75	110	72	46	75	57	40	87	83	107	48	139
New Sudbury	-	-	-	-	-	-	144	218	82	122	90	105	57	79	98	78	83	140
Lockerby	-	-	-	-	-	105	131	133	178	68	52	-	-	-	-	-	-	-
Garson	178	240	197	121	134	199	71**	-	-	-	-	-	-	-	-	-	-	91
Falconbridge Road	-	-	-	-	-	-	162**	127	65	107	114	56	104	109	154	71	92	-
Skead	177	252	180	228	183	223	221	232	116	79	68	85	75	148	210	79	84	80
Chiniguchi Lake	-	-	-	-	-	48	59	55	42	37	27	36	-	-	-	-	-	-
Grassy Lake	162	57	38	37	99	37	57	44	31	27	-	-	-	-	-	-	-	-
Lake Temagami	-	-	-	-	-	27	42	21	22	37	20	19	26	15	16	11	-	-
Coniston	-	-	-	-	96	99	124	89	188	87	151	97	47	66	58	58	40	92
Callum	175	136	148	71	111	55	82	74	58	43	60	41	21	62	39	34	-	-
St. Charles	172	26	16	24	43	44	62	28	23	21	20	23	13	25	-	-	-	-
Verner	-	-	64	16	26	32	28	22	58	12	3	-	-	-	-	-	-	-
Burwash	170	106	40	63	61	49	49	61	33	46	70	41	39	50	50	47	-	-
Hanmer	-	-	-	39*	177	92	128	160	87	72	108	61	44	74	122	71	39	101
Rayside	178	188	158	138	349	154	86	93	154	125	68	51	53	42	130	50	-	90
Morgan	172	126	109	41	122	44	111	197	25	33	-	-	-	-	-	-	-	-
Lake Penage	173	120	116	114	66	89	104	78	33	33	55	94	-	-	-	-	-	-
Kukagami	165	220	137	53	103	-	-	-	-	-	-	-	-	-	-	-	-	-
Long Lake Road	-	-	-	-	-	-	-	-	-	-	-	107	24	214	114	118	98	107
Happy Valley	-	-	-	-	-	-	-	-	-	-	-	189	162	-	-	-	-	-
Laurentian Hospital	-	-	-	-	-	-	-	-	-	-	-	83	36	64	66	-	-	-
Mikkola	-	-	-	-	-	-	-	-	-	-	-	-	49	114	113	126	100	91
High Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	51	2	-
Science North	-	-	-	-	-	-	-	-	-	-	-	-	-	-	86	97	96	81
Regional Road	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64	55	-

* This monitor was operated in September and October only in 1973 and the value of Maximum 1973 fumigation intensity was not used in summary.

** The Garson monitor was moved to Falconbridge Road in June, 1976.

TABLE 22

Frequency of Potentially Injurious SO_2 Fumigations
in the Sudbury Area from 1970 to 1987

Station	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	TOTAL
Garson	19	18	6	2	2	3	-	-	-	-	-	-	-	-	-	-	-	0	50
Skead	24	24	13	3	9	3	7	7	3	0	0	0	0	1	2	0	0	0	96
Kukagami	4	5	1	0	1	-*	-	-	-	-	-	-	-	-	-	-	-	-	11
Grassy Lake	0	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	-	0
Lake Penage	2	3	1	0	0	0	1	0	0	0	0	0	-	-	-	-	-	-	7
Morgan	1	1	1	0	1	0	1	1	0	0	-	-	-	-	-	-	-	-	6
Burwash	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	1
Rayside	9	8	3	2	0	1	0	0	1	1	0	0	0	0	1	0	-	0	26
St. Charles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-	-	0
Callum	5	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	-	-	9
Ash Street	-	27	9	1	4	0	0	2	0	0	0	0	0	0	0	1	0	1	45
Coniston	-	-	-	-	0	0	1	0	1	1	2	0	0	0	0	0	0	0	5
New Sudbury	-	-	-	-	-	-	4	3	-	-	-	-	-	0	0	0	0	1	8
Lockerby	-	-	-	-	-	2	1	1	2	0	0	-	-	-	-	-	-	-	6
Hanmer	-	-	-	0	3	0	2	3	0	0	1	1	0	0	1	0	0	1	12
Chiniguchi Lake	-	-	-	-	-	0	0	0	0	0	0	0	-	-	-	-	-	-	0
Lake Temagami	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	-	-	0
Verner	-	-	0	0	0	0	0	0	0	0	0	-	-	-	-	-	-	-	0
Falconbridge Road	-	-	-	-	-	-	2	2	0	1	2	0	1	2	1	0	0	-	11
Long Lake Road	-	-	-	-	-	-	-	-	-	-	-	1	0	1	1	1	0	1	5
Happy Valley	-	-	-	-	-	-	-	-	-	-	-	8	2	-	-	-	-	-	10
Laurentian Hospital	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	-	-	-	0
Mikkola	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	2	0	5
Science North	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	0
High Falls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0
Regional Road	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0
TOTAL	64	88	36	8	21	9	19	19	7	3	5	10	3	5	7	3	2	4	313
NO. OF MONITORS	10	11	12	13	14	16	17	17	16	16	14	15	13	14	14	15	11	10	

* Station relocated to Chiniguchi Lake in 1975
\- Station nonexistant

TABLE 23

Sulphur Dioxide Emissions From the Inco Limited and Falconbridge Limited Operations in the Sudbury Basin - SO_2 Emissions in Tonnes x 10^6

Year	Inco	Falconbridge	Total
1967	2.085	.297	2.382
1968	2.101	.381	2.482
1969 (strike year - Inco & Falconbridge)	1.310	.238	1.548
1970	1.991	.339	2.330
1971	1.868	.358	2.226
1972*	1.523	.324	1.847
1973**	1.186	.274	1.460
1974	1.216	.250	1.466
1975 (strike year - Inco & Falconbridge)	1.198	.195	1.393
1976***	1.219	.191	1.410
1977***	1.137	.198	1.335
1978***(strike year - Inco)	.567	.117	.684
1979***(strike year - Inco)	.408	.088	.496
1980***	.812	.123	.935
1981*	.724	.113	.837
1982* (major shutdown - Inco (9 months) & Falconbridge (6 months)	.329	.061	.390
1983+	.459	.079	.538
1984+	.685	.085	.770
1985+	.695	.074	.769
1986+	.635	.085	.720
1987+	.658	.065	.723

* Summer Vacation shutdown (Inco and Falconbridge)
** Summer Vacation shutdown (Inco)
*** Production shutdown (Falconbridge)
\+ 3-week summer shutdown (Inco and Falconbridge)

TABLE 24

Elemental Content* of Vegetation Samples Collected in Association with "Black Spotting" Incidents in the Sudbury Area, 1975, 1978 and 1981

Species (Foliage)	Year	No. Samples	Cu	Ni	Fe	Co	Zn	Cd	As	Pb	Se	S
Bean	1975	1	48	50	100	17	54	1.2	-	-	-	.22
	1978	5	77	47	283	-	-	-	4.9	16	3.40	-
	1981	1	143	155	1080	6	36	-	-	-	-	.30
	Control**	6	8	29	435	1	18	.3	-	2	.06	.3
Beet	1978	3	161	76	475	-	-	-	5.7	15	3.85	-
	Control	6	11	18	735	2	27	1.2	-	2	.07	.40
Carrot	1978	1	155	10	285	-	-	-	.4	2	.23	-
	Control	6	10	19	330	.5	51	1.9	-	.6	.02	.55
Cabbage	1978	2	40	29	490	-	-	-	2.6	8	1.20	-
	Control	6	6	21	105	2.5	45	.9	-	1.5	.06	.60
Endive	1975	1	90	63	334	9	108	2.5	-	-	-	-
	1978	6	223	118	535	-	-	-	5.8	18	4.10	-
	1981	3	125	157	1120	6	59	-	-	-	-	.6
	Control	6	22	20	1810	1	31	1.4	-	2	.1	.5
Escarole	1981	1	51	65	695	4	54	-	-	-	-	.6
	Control	3	19	12	1850	2	27	.8	-	2.5	<.02	.4
Leaf Lettuce	1978	9	188	97	589	-	-	-	4.8	16	3.61	-
	1981	8	229	167	1422	7	60	-	-	-	-	.6
	Control	6	17	17	622	.8	82	3.1	-	2	.06	.4
Potato Foliage	1981	1	197	143	1470	6	19	-	-	-	-	.5
	Control	6	13	9	1700	2.5	14	3.5	-	1	.06	.3
Tomato Foliage	1978	6	84	51	226	-	-	-	1.9	13	1.42	-
	Control	6	14	16	241	1.7	35	1.0	-	2	.06	.4

* All element concentrations are reported in ug/g except S which is in % dried weight.
** All control samples were collected at the Burwash Reserve 30 km south of Sudbury.

TABLE 25

Summary of Ozone Concentrations (parts per billion) in Ambient Air Monitored at Sudbury from 1975 to 1987

	MAXIMUM CONCENTRATIONS					NO. HOURS OVER CRITERION*					
	May	June	July	August	Sept.	May	June	July	August	Sept.	TOTAL
1975	86	71	88	103	52	5	0	4	4	0	13
1977	88	116	64	62	67	10	8	0	0	0	18
1978	106	101	118	75	53	25	2	17	0	0	44
1979	96	93	86	52	83	3	10	8	0	2	23
1980	78	66	76	55	57	0	0	0	0	0	0
1981	79	66	58	78	44	0	0	0	0	0	0
1982	87	48	99	51	49	2	0	7	0	0	9
1983	47	70	57	65	39	0	0	0	0	0	0
1984	23	51	66	70	65	0	0	0	0	0	0
1985	41	47	65	26	60	0	0	0	0	0	0
1986	51	51	88	58	70	0	0	2	0	0	2
1987	58	89	89	74	70	0	3	3	0	0	6
TOTAL						45	23	41	4	2	115

* Provincial criterion is 80 ppb for 1 hour.

TABLE 26

Concentrations of Chemical Elements in Twigs Collected in Vicinity of Highway 69N, May and June 1981

Species	Site	Distance* From Highway (m)	Element (ug/g) Na	Pb	Cu	Ni	Zn	Co	Fe
White Birch	(A)	0	2700	382	371	103	155	4	1150
		50	1650	75	151	72	158	2	515
		100	1980	38	89	65	147	2	333
		200	390	15	38	70	145	5	160
White Birch	(B)	0	1775	60	59	43	172	2	280
		150	273	17	26	29	265	2	138
Trembling Aspen	(A)	0	5400	39	52	43	95	2	194
		50	2450	26	36	74	78	2	136
		100	340	22	31	46	93	3	130
		200	185	20	23	43	56	2	100
Trembling Aspen	(B)	0	195	32	41	40	80	2	285
		150	325	10	12	17	93	4	85

TABLE 27

Concentrations of Nickel in Vegetation Exhibiting Symptoms of Nickel Toxicity Collected in the Sudbury Area

Site	Year	Species	Nickel Content of Vegetation (ug/g)	Nickel Content of Soil (ug/g)	Soil pH
A	1979	Timothy	58	-	-
		Canada Blue Grass	85	-	-
B	1979	Oats	76	80	4.5
		Oats	135	56	4.5
		*Oats	85	56	4.5
C	1981	Oats	80	40	4.5
		*Oats	188	40	4.5
D	1982	Timothy	138	2800	5.6
		*Oats	230	2800	5.6
E	1982	Lawn Grass	154	1180	6.0

* Bioassay, plants grown in growth cabinet

TABLE 28

Concentrations (ug g^{-1}) of Chemical Elements in Yellow Grass Samples Collected in the Copper Cliff Area, June 1984

LOCATION	ELEMENT										
	Cu	Ni	Fe	Co	Pb	Se	Ca	Mg	As	S	Zn
Poland Street	110*	110*	200	2	3	1.08	1800	1000	.5	1800	34
Power Street	220*	70*	580*	5*	10	1.94*	4300	870	3.8*	2900	22
Evans Street+	109*	153*	240	4	-	-	5550	2440	-	8500*	74
Arena Area	390*	-	280	-	-	3.86*	5500	3200	.9	7600*	68
Highway 17A	330*	150*	380	3*	6	1.75*	3100	1700	1.0	5900*	20
Highway 17B	170*	76*	260	2	5	1.34*	5200	4700	.5	5700*	30
Highway 17C	400*	123*	447	4*	6	3.79*	9033	5467	1.4	9600*	76

* Value exceeds the guidelines for normal concentration.

\+ Samples collected in May 1982.

TABLE 29

Concentrations (ug g^{-1}) of Chemical Elements in Soil (0-10 cm) Samples Collected Beneath Yellow Grass in the Copper Cliff Area, June 1984

LOCATION	ELEMENT										
	Cu	Ni	Fe	Co	Pb	Se	Ca	Mg	As	S	Z
Poland Street	400*	340*	25000	23	74	1.08	3700	4600	23.3*	300	9
Power Street	3000*	1950*	125000*	125*	63	2.58*	11500	5450	1740*	3500*	11
Evans Street+	1220*	650*	32500	69*	-	-	4400	5100	-	1000*	6
Arena Area	1500*	1000*	30000	41	55	5.88*	8200	4800	22.5*	-	7
Highway 17A	480*	420*	16000	15	20	1.32	5750	4950	14.0	400	3
Highway 17B	525*	320*	21000	14	26	1.22	6600	6100	11.4	400	4
Highway 17C	2100*	1300*	22000	31*	63	5.42*	5300	4400	16.1	-	11

* Value exceeds the guidelines for normal concentration.

\+ (0-15 cm) Samples collected in May 1982.

TABLE 30

Monthly Total Precipitation for the Growing Season Months, 1970-1987 at Sudbury Airport

Year	MONTHLY PRECIPITATION (mm) May	June	July	August	Total
1970	132.6	94.7	146.1	43.7	417.1
1971	73.7	40.4	94.9	55.4	264.4
1972	45.7	111.5	78.2	194.1	429.5
1973	111.3	84.6	99.3	100.8	396.0
1974	80.5	85.6	78.7	64.8	309.6
1975	71.9	55.1	35.8	21.8	184.6
1976	89.7	44.2	48.7	75.3	257.9
1977	21.7	74.6	156.7	104.3	357.3
1978	69.7	72.2	92.3	157.8	392.0
1979	47.8	79.1	80.9	97.5	305.3
1980	60.5	64.4	68.0	100.0	292.9
1981	52.0	112.2	30.8	68.7	263.7
1982	27.2	64.7	32.7	63.8	188.4
1983	137.6	38.4	41.2	111.1	328.3
1984	101.1	178.0	61.1	143.2	483.4
1985	52.4	42.0	148.3	63.0	305.7
1986	76.4	93.0	85.8	51.5	306.7
1987	70.0	58.2	45.4	43.7	217.3

TABLE 31

Average Emissions of Five Major Metals from the Inco 381 m Stack in Kilograms/Hour

YEAR	Iron*	Copper*	Nickel*	Lead	Arsenic
1973	127	31	29	21	11
1974	163	39	37	29	10
1975	166	39	38	23	23
1976	169	39	39	12	15
1977	156	37	35	18	8
1978	52	14	12	10	-
1979	23	8	6	-	-
1980	89	22	21	34	10
1981	73	19	17	-	-
AVERAGE	113	28	26	21	13

* Emissions calculated from regression lines.

This table was extracted from the publication "Emissions of Sulphur Oxides, Particulates and Trace Elements in the Sudbury Basin" (Ozvacic, 1982).

TABLE 32

Concentrations of Copper (ug/g) in White Birch Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1975	1976	1979	1984
Blind River*	160 km W	8	7	9	9	5	6	6	4
Wattawa*	176 km E	10	6	9	8	6	5	6	7
Sudbury	0 km	26	23	25	19	61	24	13	21
Milnet	37 km N	26	9	8	10	11	11	7	9
Chiniguchi Lake	57 km NNE	--	--	--	6	14	8	6	7
Garson	5 km NE	61	48	24	26	52	22	27	27
Skead	26 km NE	59	25	14	29	58	22	12	12
Kukagami Lake	42 km NE	39	14	10	12	17	9	7	7
Grassy Lake	64 km NE	11	10	13	10	11	11	6	6
Lake Temagami	80 km NE	20	11	13	11	10	8	6	7
Callum	29 km E	23	24	9	11	14	8	8	11
Sturgeon Falls	77 km E	12	8	9	9	9	6	6	6
St. Charles	48 km SE	16	8	7	9	12	8	6	7
Burwash	27 km S	23	12	12	11	13	11	6	7
Tilton Lake	15 km SW	--	--	--	15	29	24	13	13
Lake Penage	37 km SW	22	9	13	7	11	11	6	8
Killarney	64 km SW	--	--	9	8	9	13	7	7
Nairn Centre	48 km WSW	10	11	13	10	7	8	6	7
Fairbanks Park	37 km W	--	--	--	7	7	9	6	7
Rayside Township	16 km NW	24	21	13	14	25	17	9	19
Morgan Township	24 km NW	19	16	13	8	12	8	6	7

Background Concentration Guideline = 20 ug Cu/g tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1973 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 33

Concentrations of Nickel (ug/g) in White Birch Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1975	1976	1979	1984
Blind River*	160 km W	3	8	7	4	7	5	2	2
Mattawa*	176 km E	3	5	5	4	7	9	1	5
Sudbury	0 km	58	81	82	77	112	93	57	73
Milnet	37 km N	42	16	25	19	16	23	14	16
Chiniguchi Lake	57 km NNE	--	--	--	20	24	17	8	10
Garson	5 km NE	84	81	61	86	133	102	39	76
Skead	26 km NE	97	72	76	72	110	78	42	38
Kukagami Lake	42 km NE	46	25	47	16	38	37	11	10
Grassy Lake	64 km NE	13	11	16	11	24	16	8	5
Lake Temagami	80 km NE	14	10	16	10	18	14	6	9
Callum	29 km E	44	45	44	47	58	33	39	29
Sturgeon Falls	77 km E	7	8	8	7	10	14	5	8
St. Charles	48 km SE	16	13	8	11	16	22	9	11
Burwash	27 km S	31	25	31	32	36	39	25	15
Tilton Lake	15 km SW	--	--	--	58	59	78	13	49
Lake Penage	37 km SW	13	10	19	16	22	28	12	18
Killarney	64 km SW	--	--	10	7	15	12	8	8
Nairn Centre	48 km WSW	8	13	12	8	10	10	10	12
Fairbanks Park	37 km W	--	--	--	15	18	16	11	16
Rayside Township	16 km NW	45	40	48	59	58	49	30	43
Morgan Township	24 km NW	18	23	19	13	19	11	12	11

Background Concentration Guideline = 30 ug Ni/g tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1973 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 34

Concentrations of Arsenic (ug/g) in White Birch Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1975	1976	1979	1984
Blind River*	160 km W	.5	.6	.8	<.4	<.3	0.3	<.3	<.03
Mattawa*	176 km E	.6	1.1	.4	<.4	<.3	0.3	<.3	<.03
Sudbury	0 km	.5	2.8	1.2	1.8	2.0	.9	.3	.7
Milnet	37 km N	1.4	1.7	1.6	1.6	.7	.3	<.3	.08
Chiniguchi Lake	57 km NNE	--	--	--	.6	1.1	.5	<.3	<.03
Garson	5 km NE	2.0	5.4	1.8	1.7	2.7	1.7	.4	1.59
Skead	26 km NE	4.4	3.6	2.4	2.4	8.5	1.9	.6	.36
Kukagami Lake	42 km NE	2.2	1.9	1.6	.8	1.5	1.1	<.3	.15
Grassy Lake	64 km NE	.7	1.5	.7	<.4	.8	.5	<.3	.02
Lake Temagami	80 km NE	.6	1.3	.7	<.4	.6	.4	<.3	.16
Callum	29 km E	1.1	1.4	1.0	.6	1.1	.7	<.3	.14
Sturgeon Falls	77 km E	.7	1.4	.6	<.4	.4	.3	<.3	.11
St. Charles	48 km SE	.7	1.0	.5	<.4	.9	.4	<.3	.09
Burwash	27 km S	.7	1.4	.6	.4	1.0	.6	<.3	.05
Tilton Lake	15 km SW	--	--	--	1.6	1.7	1.1	<.3	.39
Lake Penage	37 km SW	.5	1.2	.4	<.4	.8	.4	<.3	.09
Killarney	64 km SW	--	--	--	<.4	.3	.4	<.3	<.03
Nairn Centre	48 km WSW	.6	1.7	1.0	.4	<.3	.5	<.3	<.03
Fairbanks Park	37 km W	--	--	--	.4	.3	.4	<.3	.06
Rayside Township	16 km NW	.7	1.6	.6	1.6	1.4	.8	.3	.28
Morgan Township	24 km NW	.5	1.4	.7	.6	.5	.3	<.3	.05

Background Concentration Guideline = 2 ug As/g tissue

* Control Location

** Values reported are means of four month samples in 1970, three monthly samples in 1971 through 1973 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 35

Concentrations of Selenium (ug/g) in White Birch Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1972	1973	1979	1984
Blind River*	160 km W	--	--	.20	.18	<.03
Mattawa*	176 km E	.70	--	.17	.14	.06
Sudbury	0 km	--	--	.46	.15	.59
Milnet	37 km N	--	--	.30	.17	.20
Chiniguchi Lake	57 km NNE	--	--	.18	.16	.11
Garson	5 km NE	1.06	.25	.30	.27	1.13
Skead	26 km NE	.79	.16	.40	.17	.38
Kukagami Lake	42 km NE	.93	--	.26	.15	.20
Grassy Lake	64 km NE	.79	--	.30	.16	<.03
Lake Temagami	80 km NE	.74	--	.18	.19	<.03
Callum	29 km E	--	.27	.33	.15	.2
Sturgeon Falls	77 km E	--	--	.14	.15	<.03
St. Charles	48 km SE	--	.22	.18	.15	.13
Burwash	27 km S	--	.15	.15	.14	<.03
Tilton Lake	15 km SW	--	--	.42	.14	.6
Lake Penage	37 km SW	.77	--	.33	.13	.38
Killarney	64 km SW	--	--	.15	.16	<.03
Nairn Centre	48 km WSW	--	--	.19	.14	<.03
Fairbanks Park	37 km W	--	--	.27	.15	<.03
Rayside Township	16 km NW	--	--	.38	.16	.52
Morgan Township	24 km NW	--	--	.30	.15	<.03

Background Concentration Guideline = 0.5 ug Se/g tissue.

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1972 and 1973, and two monthly samples in triplicate in 1979 and 1984

TABLE 36

Concentrations of Iron (ug/g) in White Birch Foliage Samples
Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1975	1976	1979	1984
Blind River*	160 km W	54	97	79	81	163	170	167	129
Mattawa*	176 km E	54	74	51	101	76	110	69	55
Sudbury	0 km	162	311	163	152	435	169	157	155
Milnet	37 km N	141	147	157	196	264	133	132	141
Chiniguchi Lake	57 km NNE	--	--	--	94	188	61	84	106
Garson	5 km NE	235	360	136	183	340	188	201	199
Skead	26 km NE	423	342	229	170	466	210	139	96
Kukagami Lake	42 km NE	321	133	79	108	152	123	97	119
Grassy Lake	64 km NE	103	95	85	88	150	196	117	128
Lake Temagami	80 km NE	137	345	150	171	1073	474	115	100
Callum	29 km E	125	187	139	137	323	160	208	98
Sturgeon Falls	77 km E	44	122	121	106	382	68	200	91
St. Charles	48 km SE	110	176	109	99	337	214	211	292
Burwash	27 km S	186	156	125	171	446	156	99	212
Tilton Lake	15 km SW	--	--	--	161	363	292	173	130
Lake Penage	37 km SW	74	71	93	81	476	242	200	94
Killarney	64 km SW	--	--	75	90	98	200	238	98
Nairn Centre	48 km WSW	75	92	85	92	93	83	163	90
Fairbanks Park	37 km W	--	--	--	67	97	50	230	102
Rayside Township	16 km NW	130	447	152	173	406	198	114	143
Morgan Township	24 km NW	140	267	215	151	571	144	72	77

Background Concentration Guideline = 500 ug Fe/g tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1973 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 37

Concentrations of Lead (ug/g) in White Birch Foliage Samples Collected in the Sudbury Area 1973-1984**

Plot	Distance and Direction from Sudbury	1973	1975	1976	1979	1984
Blind River*	160 km W	6	8	4	4	1
Mattawa*	176 km E	6	6	4	2	1.7
Sudbury	0 km	10	13	7	4	4
Milnet	37 km N	4	10	8	3	2.5
Chiniguchi Lake	57 km NNE	9	8	8	5	1.8
Garson	5 km NE	5	12	7	4	4.8
Skead	26 km NE	6	13	10	3	2.7
Kukagami Lake	42 km NE	3	9	8	2	2.2
Grassy Lake	64 km NE	4	10	8	3	<1.0
Lake Temagami	80 km NE	6	10	8	4	2.8
Callum	29 km E	7	10	6	4	2.2
Sturgeon Falls	77 km E	6	10	5	2	2.8
St. Charles	48 km SE	4	10	5	2	2
Burwash	27 km S	10	12	12	4	1.8
Tilton Lake	15 km SW	14	13	8	3	2.5
Lake Penage	37 km SW	6	12	12	4	2.5
Killarney	64 km SW	8	11	14	6	2.3
Nairn Centre	48 km WSW	11	9	6	4	3.5
Fairbanks Park	37 km W	5	7	10	5	3.2
Rayside Township	16 km NW	6	10	11	3	3.2
Morgan Township	24 km NW	6	9	12	2	1.8

Background Concentration Guideline = 30 ug Pb/g tissue.

* Control Location

** Values reported are means of three monthly samples in 1973 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 38

Concentrations of Sulphur (% dry weight) in White Birch Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1975	1976	1979	1984
Blind River*	160 km W	.12	.14	.13	.14	.10	.09	.17	.11
Mattawa*	176 km E	.17	.13	.16	.16	.09	.11	.14	.13
Sudbury	0 km	.29	.35	.25	.18	.19	.13	.15	.14
Milnet	37 km N	.25	.15	.25	.21	.14	.11	.17	.14
Chiniguchi Lake	57 km NNE	--	--	--	.21	.17	.11	.15	.13
Garson	5 km NE	.41	.48	.30	.25	.30	.26	.23	.15
Skead	26 km NE	.37	.36	.30	.32	.35	.19	.29	.16
Kukagami Lake	42 km NE	.27	.29	.21	.22	.21	.16	.16	.10
Grassy Lake	64 km NE	.18	.24	.16	.16	.13	.13	.16	.14
Lake Temagami	80 km NE	.22	.21	.19	.15	.16	.13	.19	.12
Callum	29 km E	.24	.33	.20	.19	.13	.12	.15	.13
Sturgeon Falls	77 km E	.17	.19	.18	.14	.13	.09	.15	.12
St. Charles	48 km SE	.15	.20	.15	.12	.14	.13	.14	.11
Burwash	27 km S	.26	.23	.26	.17	.16	.14	.15	.15
Tilton Lake	15 km SW	--	--	--	.17	.18	.14	.14	.14
Lake Penage	37 km SW	.17	.21	.23	.18	.12	.13	.13	.15
Killarney	64 km SW	--	--	.18	.14	.16	.16	.16	.14
Nairn Centre	48 km WSW	.17	.18	.19	.15	.13	.12	.14	.13
Fairbanks Park	37 km W	--	--	--	.14	.10	.09	.15	.12
Rayside Township	16 km NW	.24	.22	.19	.24	.19	.13	.17	.14
Morgan Township	24 km NW	.17	.31	.22	.17	.12	.09	.15	.11

Background Concentration Guideline = .4% S tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1973 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 39

Concentrations of Copper (ug/g) in Grass Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1974	1979	1984
Blind River*	160 km W	9	5	8	5	6	4	3
Mattawa*	176 km E	9	5	2	3	4	4	3
Sudbury	0 km	18	7	17	7	18	5	5
Milnet	37 km N	15	10	18	6	7	4	4
Chiniguchi Lake	57 km NNE	--	--	--	5	3	9	2
Garson	5 km NE	35	12	58	11	22	7	7
Skead	26 km NE	36	12	19	10	39	6	6
Kukagami Lake	42 km NE	18	11	15	7	12	5	6
Grassy Lake	64 km NE	12	12	6	6	3	4	8
Lake Temagami	80 km NE	12	7	4	5	5	4	7
Callum	29 km E	16	8	9	6	14	3	5
Sturgeon Falls	77 km E	11	9	5	7	5	6	3
St. Charles	48 km SE	10	5	5	4	8	4	4
Burwash	27 km S	17	8	3	5	6	3	5
Tilton Lake	15 km SW	--	--	--	7	7	8	13
Lake Penage	37 km SW	19	8	12	6	6	4	3
Killarney	64 km SW	--	--	8	10	5	6	6
Nairn Centre	48 km WSW	8	8	5	7	5	4	6
Fairbanks Park	37 km W	--	--	--	3	2	8	8
Rayside Township	16 km NW	14	7	20	6	16	6	5
Morgan Township	24 km NW	13	9	17	7	7	5	6

Background Concentration Guideline = 20 ug Cu/g tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly sample 1971 through 1974 and two monthly samples in triplicate in 1979 and 1984.

TABLE 40

Concentrations of Nickel (ug/g) in Grass Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1974	1979	1984
Blind River*	160 km W	2	2	5	3	5	1	<1
Mattawa*	176 km E	3	8	4	3	3	2	1
Sudbury	0 km	24	34	51	26	47	40	28
Milnet	37 km N	37	3	10	16	22	10	14
Chiniguchi Lake	57 km NNE	--	--	--	10	15	8	3
Garson	5 km NE	15	36	65	22	40	28	40
Skead	26 km NE	33	29	36	36	36	32	23
Kukagami Lake	42 km NE	22	40	7	8	46	11	6
Grassy Lake	64 km NE	6	7	8	7	9	12	7
Lake Temagami	80 km NE	3	11	7	7	6	6	6
Callum	29 km E	30	29	49	22	32	39	28
Sturgeon Falls	77 km E	3	9	5	4	4	5	4
St. Charles	48 km SE	7	14	11	10	4	9	7
Burwash	27 km S	20	13	21	24	25	10	3
Tilton Lake	15 km SW	--	--	--	24	52	18	32
Lake Penage	37 km SW	7	15	15	9	7	7	6
Killarney	64 km SW	--	--	10	13	8	6	8
Nairn Centre	48 km WSW	5	10	9	6	10	5	5
Fairbanks Park	37 km W	--	--	--	7	10	13	19
Rayside Township	16 km NW	30	24	36	29	24	19	12
Morgan Township	24 km NW	19	5	30	8	9	7	5

Background Concentration Guideline = 25 ug Ni/g tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1979 and 1984.

TABLE 41

Concentrations of Arsenic (ug/g) in Grass Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1974	1979	1984
Blind River*	160 km W	<.5	.9	.8	<.4	<.3	<.3	.03
Mattawa*	176 km E	.5	1.1	.9	.4	<.3	<.3	.04
Sudbury	0 km	<.5	2.0	2.3	2.2	.7	.3	.34
Milnet	37 km N	.5	1.3	.6	.3	.3	<.3	.07
Chiniguchi Lake	57 km NNE	--	--	--	.7	.3	<.3	.06
Garson	5 km NE	2.1	3.5	2.0	1.6	1.0	.3	.61
Skead	26 km NE	1.2	3.7	1.1	1.6	2.2	.3	.27
Kukagami Lake	42 km NE	.9	.8	.6	<.5	.8	<.3	.13
Grassy Lake	64 km NE	.6	1.1	.7	.5	<.3	<.3	.04
Lake Temagami	80 km NE	<.5	1.5	.9	<.5	<.3	<.3	.10
Callum	29 km E	.7	1.6	.8	.5	.9	<.3	.1
Sturgeon Falls	77 km E	<.5	1.4	.7	<.5	<.3	<.3	.11
St. Charles	48 km SE	<.5	1.4	.4	.5	<.3	<.4	.08
Burwash	27 km S	1.2	1.4	.7	1.1	.4	<.3	.04
Tilton Lake	15 km SW	--	--	--	.8	.3	.4	.50
Lake Penage	37 km SW	<.5	1.4	.5	.6	<.3	<.3	.12
Killarney	64 km SW	--	--	.7	<.4	<.3	<.3	<.03
Nairn Centre	48 km WSW	<.5	1.0	.6	<.4	<.3	<.3	<.03
Fairbanks Park	37 km W	--	--	--	<.4	<.3	<.3	.05
Rayside Township	16 km NW	<.5	1.9	1.2	.6	1.0	<.3	.21
Morgan Township	24 km NW	<.5	1.1	.4	.6	.3	<.3	<.03

Background Concentration Guideline = 8 ug As/g tissue

* Control Location

** Values reported are means of four monthly samples in 1970 an three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1979 and 1984.

TABLE 42

Concentrations of Selenium (ug/g) in Grass Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1972	1973	1979	1984
Blind River*	160 km W	--	.16	.14	.11	.05
Mattawa*	176 km E	.52	.15	.13	.18	<.03
Sudbury	0 km	--	.22	.36	.14	.18
Milnet	37 km N	--	.19	.35	.19	<.03
Chiniguchi Lake	57 km NNE	--	--	.27	.23	.06
Garson	5 km NE	.81	.33	.46	.15	.60
Skead	26 km NE	.67	.20	.51	.27	.07
Kukagami Lake	42 km NE	.58	.15	.25	.10	.09
Grassy Lake	64 km NE	.48	.14	.20	.19	<.03
Lake Temagami	80 km NE	.45	.17	.24	.36	<.03
Callum	29 km E	--	.18	.23	.15	.08
Sturgeon Falls	77 km E	--	.08	.12	.16	.06
St. Charles	48 km SE	--	.08	.11	.15	<.03
Burwash	27 km S	--	.16	.18	.37	<.03
Tilton Lake	15 km SW	--	--	.12	.29	.33
Lake Penage	37 km SW	.57	.20	.22	.15	.10
Killarney	64 km SW	--	.12	.11	.13	<.03
Nairn Centre	48 km WSW	--	.14	.14	.10	.04
Fairbanks Park	37 km W	--	--	.12	.26	.03
Rayside Township	16 km NW	--	.29	.33	.15	.17
Morgan Township	24 km NW	--	.14	.13	.16	<.03

Background Concentration Guideline = 0.5 ug Se/g tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1972 and 1973 and two monthly samples in triplicate in 1979 and 1984.

TABLE 43

Concentrations of Iron (ug/g) in Grass Foliage Samples
Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1974	1979	1984
Blind River*	160 km W	40	70	79	80	48	108	80
Mattawa*	176 km E	100	122	158	82	127	145	40
Sudbury	0 km	121	291	69	67	126	89	36
Milnet	37 km N	98	98	151	287	140	54	56
Chiniguchi Lake	57 km NNE	--	--	--	121	57	571	63
Garson	5 km NE	122	267	262	122	112	158	64
Skead	26 km NE	234	281	241	126	85	173	80
Kukagami Lake	42 km NE	112	237	87	114	183	146	93
Grassy Lake	64 km NE	73	95	155	107	65	124	114
Lake Temagami	80 km NE	148	453	163	193	106	155	126
Callum	29 km E	110	134	119	183	132	133	36
Sturgeon Falls	77 km E	82	268	63	98	59	204	80
St. Charles	48 km SE	97	141	119	84	86	219	147
Burwash	27 km S	108	376	70	106	263	130	65
Tilton Lake	15 km SW	--	--	--	118	41	220	102
Lake Penage	37 km SW	79	85	147	54	63	466	53
Killarney	64 km SW	--	--	62	133	122	238	185
Nairn Centre	48 km WSW	59	96	46	93	146	142	69
Fairbanks Park	37 km W	--	--	--	31	87	219	74
Rayside Township	16 km NW	139	278	240	88	137	74	57
Morgan Township	24 km NW	115	346	174	214	148	95	43

Background Concentration Guideline = 500 ug Fe/g tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1979 and 1984.

TABLE 44

Concentrations of Lead (ug/g) in Grass Foliage Samples
Collected in the Sudbury Area 1973-1984**

Plot	Distance and Direction from Sudbury	1973	1979	1984
Blind River*	160 km W	4	2	1.5
Mattawa*	176 km E	4	2	<1.0
Sudbury	0 km	12	2	<1.0
Milnet	37 km N	6	2	<1.0
Chiniguchi Lake	57 km NNE	7	7	1.7
Garson	5 km NE	6	2	<1.0
Skead	26 km NE	5	2	3.3
Kukagami Lake	42 km NE	4	5	1.7
Grassy Lake	64 km NE	8	2	1.3
Lake Temagami	80 km NE	4	2	3
Callum	29 km E	3	2	<1
Sturgeon Falls	77 km E	3	2	1.17
St. Charles	48 km SE	3	2	2.17
Burwash	27 km S	4	2	<1.0
Tilton Lake	15 km SW	8	2	<1.0
Lake Penage	37 km SW	12	3	1.2
Killarney	64 km SW	4	2	1.7
Nairn Centre	48 km WSW	8	6	1.5
Fairbanks Park	37 km W	4	2	2
Rayside Township	16 km NW	5	2	<1.0
Morgan Township	24 km NW	5	2	<1.0

Background Concentration Guideline = 20 ug Pb/g tissue

* Control Location

** Values reported are means of three monthly samples in 1973 and two monthly samples in triplicate in 1979 and 1984.

TABLE 45

Concentrations of Sulphur (% dry weight) in Grass Foliage Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	1970	1971	1972	1973	1974	1979	1984
Blind River*	160 km W	.14	.19	.18	.13	.21	.12	.14
Mattawa*	176 km E	.20	.15	.09	.18	.12	.18	.17
Sudbury	0 km	.22	.22	.19	.17	.28	.14	.07
Milnet	37 km N	.30	.28	.31	.25	.23	.19	.13
Chiniguchi Lake	57 km NNE	--	--	--	.25	.14	.23	.11
Garson	5 km NE	.40	.28	.37	.16	.21	.24	.15
Skead	26 km NE	.41	.40	.30	.39	.36	.26	.15
Kukagami Lake	42 km NE	.31	.31	.34	.19	.29	.13	.11
Grassy Lake	64 km NE	.28	.34	.20	.16	.17	.19	.13
Lake Temagami	80 km NE	.19	.18	.17	.15	.17	.36	.17
Callum	29 km E	.25	.25	.22	.22	.25	.15	.19
Sturgeon Falls	77 km E	.14	.31	.16	.16	.14	.16	.10
St. Charles	48 km SE	.22	.19	.21	.16	.21	.16	.10
Burwash	27 km S	.25	.24	.30	.17	.25	.37	.21
Tilton Lake	15 km SW	--	--	--	.15	.26	.29	.27
Lake Penage	37 km SW	.23	.21	.18	.25	.25	.15	.08
Killarney	64 km SW	--	--	.17	.18	.26	.14	.10
Nairn Centre	48 km WSW	.19	.22	.19	.15	.17	.11	.13
Fairbanks Park	37 km W	--	--	--	.06	.19	.26	.13
Rayside Township	16 km NW	.27	.26	.23	.23	.16	.15	.14
Morgan Township	24 km NW	.29	.26	.24	.22	.14	.16	.17

Background Concentration Guideline = .5% S tissue

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1979 and 1984.

TABLE 46

Concentrations of Copper (ug/g) in Soil Samples Collected in the Sudbury Area 1970-1984***

Plot	Distance and Direction from Sudbury	YEAR**							1979			1984		
		1970	1971	1972	1973	1974	1975	1976	0-5	5-10	10-15	0-5	5-10	10-15
									cm			cm		
Blind River*	160 km W	10	18	5	5	26	7	7	12	12	12	10	10	13
Mattawa*	176 km E	7	7	3	4	6	9	7	8	7	9	4	3	2
Sudbury	0 km	265	173	187	268	82	216	106	340	79	38	438	70	32
Milnet	37 km N	33	19	16	9	5	17	17	20	11	11	31	9	6
Chiniguchi Lake	57 km NNE	--	--	--	14	15	35	20	25	6	7	20	6	4
Garson	5 km NE	174	105	57	87	56	100	127	89	35	49	85	54	40
Skead	26 km NE	125	170	181	179	182	80	92	137	56	25	200	51	48
Kukagami Lake	42 km NE	102	35	119	40	32	52	62	112	30	26	101	75	62
Grassy Lake	64 km NE	57	28	44	41	34	60	40	38	30	36	23	25	15
Lake Temagami	80 km NE	51	22	39	18	34	37	28	47	36	29	39	22	22
Callum	29 km E	94	37	75	30	18	103	48	79	15	12	147	27	17
Sturgeon Falls	77 km E	23	16	23	20	31	22	15	20	13	7	18	13	13
St. Charles	48 km SE	21	24	12	12	25	24	23	37	23	23	26	18	16
Burwash	27 km S	27	39	10	29	4	15	44	38	11	11	62	27	20
Tilton Lake	15 km SW	--	--	--	125	26	118	72	276	138	83	125	13	18
Lake Penage	37 km SW	58	82	31	32	28	99	75	101	12	15	52	39	44
Killarney	64 km SW	--	--	--	43	8	10	15	17	10	11	16	8	6
Nairn Centre	48 km WSW	44	17	40	78	24	30	42	16	10	8	58	31	36
Fairbanks Park	37 km W	--	--	--	16	43	26	36	37	18	26	52	21	7
Rayside Township	16 km NW	67	45	88	68	68	138	72	40	19	14	125	7	4
Morgan Township	24 km NW	29	20	18	16	14	17	18	12	12	16	30	11	6

Normal Concentration Guideline = 60 ug Cu/g Soil

* Control Location

** Soil Depth 0-10 cm for samples collected in 1970-1976.

*** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 47

Concentrations of Nickel (ug/g) in Soil Samples Collected in the Sudbury Area 1970-1984***

Plot	Distance and Direction from Sudbury	YEAR**							1979			1984		
		1970	1971	1972	1973	1974	1975	1976	0-5	5-10	10-15	0-5	5-10	10-15
									cm			cm		
Blind River*	160 km W	11	2	11	4	16	15	12	5	7	9	10	10	11
Mattawa*	176 km E	7	5	28	4	10	18	24	7	6	6	5	4	7
Sudbury	0 km	245	149	235	187	92	343	87	354	87	82	332	45	36
Milnet	37 km N	50	18	20	60	26	26	34	22	15	15	33	16	17
Chiniguchi Lake	57 km NNE	--	--	--	19	25	42	63	19	6	8	28	9	6
Garson	5 km NE	215	86	76	97	50	155	138	71	36	42	82	48	41
Skead	26 km NE	150	135	116	132	169	87	77	111	41	41	123	49	50
Kukagami Lake	42 km NE	85	42	83	37	45	77	68	90	26	22	88	87	63
Grassy Lake	64 km NE	68	53	40	34	48	63	49	44	39	36	29	31	26
Lake Temagami	80 km NE	40	32	28	19	36	33	61	45	33	29	41	32	30
Callum	29 km E	60	48	94	55	29	134	58	85	22	22	135	48	29
Sturgeon Falls	77 km E	39	34	65	19	26	23	25	8	8	4	19	19	20
St. Charles	48 km SE	31	45	63	25	34	32	43	35	22	22	30	22	21
Burwash	27 km S	44	59	27	73	26	26	72	42	14	13	68	28	27
Tilton Lake	15 km SW	--	--	--	95	76	170	98	389	138	88	105	24	23
Lake Penage	37 km SW	79	49	44	29	53	89	59	140	16	11	78	64	73
Killarney	64 km SW	--	--	20	14	20	22	19	12	8	10	15	10	8
Nairn Centre	48 km WSW	52	40	38	23	53	37	36	13	11	11	46	21	28
Fairbanks Park	37 km W	--	--	43	19	34	38	31	28	19	28	48	18	14
Rayside Township	16 km NW	85	37	136	62	87	170	72	42	26	24	168	12	8
Morgan Township	24 km NW	43	23	42	24	19	34	30	13	12	12	37	17	12

Normal Concentration Guideline = 60 ug Ni/g Soil

* Control Location

** Soil Depth 0-10 cm for samples collected in 1970-1976.

*** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 48

Concentrations of Arsenic (ug/g) in Soil Samples Collected in the Sudbury Area 1970-1984***

Plot	Distance and Direction from Sudbury	YEAR**							1979			1984		
		1970	1971	1972	1973	1974	1975	1976	0-5	5-10	10-15	0-5	5-10	10-15
									cm			cm		
Blind River*	160 km W	1.7	4.4	2.2	2.3	2.4	1.4	.9	1.0	.6	2.4	2.3	1.9	1.7
Mattawa*	176 km E	2.3	3.8	2.9	.9	1.2	.8	.8	.4	.3	.3	1.3	.8	.8
Sudbury	0 km	10.2	18.4	12.4	8.7	6.9	16.9	5.9	16.7	8.7	3.2	33.1	8.1	4.6
Milnet	37 km N	7.2	4.8	3.0	5.9	2.9	2.8	7.6	2.2	.7	.7	11.3	9.2	7.3
Chiniguchi Lake	57 km NNE	--	--	--	3.9	3.0	7.1	1.9	2.1	.9	1.4	3.6	2.3	1.4
Garson	5 km NE	9.8	26.0	7.6	10.4	4.4	14.1	6.6	11.9	5.0	6.7	8.4	4.5	3.5
Skead	26 km NE	13.1	47.0	43.7	8.0	10.4	16.2	11.0	16.3	5.2	3.6	30.2	8.5	7.1
Kukagami Lake	42 km NE	11.7	6.4	13.4	6.3	5.4	7.9	6.7	8.6	3.8	3.0	14.0	9.6	8.6
Grassy Lake	64 km NE	7.0	6.6	11.4	5.9	8.4	8.1	4.2	4.5	4.2	3.3	4.0	3.9	2.9
Lake Temagami	80 km NE	4.0	7.0	8.0	2.4	3.3	2.5	3.6	3.0	2.6	2.1	5.5	3.5	3.5
Callum	29 km E	11.0	7.7	3.2	2.6	2.7	8.6	4.7	6.8	4.0	2.4	9.9	4.0	3.9
Sturgeon Falls	77 km E	5.6	5.6	4.4	2.5	2.0	1.7	1.0	1.9	1.5	1.4	3.1	1.9	1.4
St. Charles	48 km SE	7.3	6.5	3.2	2.6	2.8	2.9	2.4	3.7	2.9	2.1	4.7	3.6	3.1
Burwash	27 km S	3.4	6.7	5.8	3.2	1.4	1.1	3.7	2.4	2.0	1.0	7.0	4.9	3.9
Tilton Lake	15 km SW	--	--	--	8.5	8.9	19.5	7.9	15.6	1.0	7.2	9.5	3.7	3.6
Lake Penage	37 km SW	7.2	8.7	9.8	3.7	4.8	4.1	5.1	3.0	3.5	1.5	5.9	5.2	5.1
Killarney	64 km SW	--	--	5.8	2.2	2.2	4.2	1.3	1.8	.8	1.5	3.6	1.7	1.2
Nairn Centre	48 km WSW	3.9	4.8	1.2	2.5	3.9	4.0	3.5	.3	.8	.4	3.4	1.9	2.0
Fairbanks Park	37 km W	--	--	--	9.7	6.3	5.9	6.7	5.9	5.9	7.4	6.2	4.5	3.7
Rayside Township	16 km NW	7.0	8.0	7.7	6.6	7.3	13.2	6.0	4.8	2.6	2.1	8.9	3.2	2.6
Morgan Township	24 km NW	3.4	2.9	4.2	2.5	1.2	1.0	1.0	.7	.5	.4	4.0	1.8	.8

Normal Concentration Guideline = 10 ug As/g Soil

* Control Location

** Soil Depth 0-10 cm for samples collected in 1970-1976.

*** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 49

Concentrations of Selenium (ug/g) in Soil Samples Collected in the Sudbury Area 1970-1984**

Plot	Distance and Direction from Sudbury	YEAR				
		1970	1972	1984		
		0-10 cm	0-10 cm	0-5 cm	5-10 cm	10-15 cm
Blind River*	160 km W	.75	.23	.22	.17	.11
Mattawa*	176 km E	.08	.20	.14	.08	.12
Sudbury	0 km	--	1.02	2.9	1.06	.79
Milnet	37 km N	--	.34	.66	.44	.38
Chiniguchi Lake	57 km NNE	--	--	.42	.11	.10
Garson	5 km NE	1.52	.35	.62	.34	.27
Skead	26 km NE	.29	.64	1.50	1.46	.70
Kukagami Lake	42 km NE	.47	.80	1.80	1.40	1.13
Grassy Lake	64 km NE	.32	.23	1.74	.38	.26
Lake Temagami	80 km NE	.30	.40	.63	.34	.35
Callum	29 km E	--	.36	1.11	.58	.53
Sturgeon Falls	77 km E	--	.41	.74	.41	.43
St. Charles	48 km SE	--	.34	.83	.58	.38
Burwash	27 km S	--	.36	.57	.52	.47
Tilton Lake	15 km SW	--	--	2.46	1.05	1.03
Lake Penage	37 km SW	.40	.23	2.47	1.84	2.43
Killarney	64 km SW	--	.25	.24	.15	.14
Nairn Centre	48 km WSW	--	.37	.85	.24	.34
Fairbanks Park	37 km W	--	--	1.64	.55	.57
Rayside Township	16 km NW	--	.42	1.19	<.03	.15
Morgan Township	24 km NW	--	.23	.66	.38	.06

Normal Concentration Guideline = 2 ug Se/g Soil

* Control Location

** Values reported are means of four monthly samples in 1970, three monthly samples in 1972 and two monthly samples in 1984.

TABLE 50

Concentrations of Iron (% dry weight) in Soil Samples Collected in the Sudbury Area 1970-1984***

Plot	Distance and Direction from Sudbury	YEAR**							1979			1984		
		1970	1971	1972	1973	1974	1975	1976	0-5	5-10	10-15	0-5	5-10	10-15
									cm			cm		
Blind River*	160 km W	.15	.67	.95	.95	1.07	.98	.67	.53	.74	.63	.92	1.03	1.10
Mattawa*	176 km E	.39	.65	.65	.46	.56	.94	.72	.63	.74	.76	.73	.83	1.33
Sudbury	0 km	1.58	1.15	1.15	.51	1.35	1.30	1.04	1.71	1.81	1.71	1.57	1.9	1.77
Milnet	37 km N	.97	.56	.56	.64	.97	.98	.87	.86	.85	.84	1.12	1.20	1.20
Chiniguchi Lake	57 km NNE	--	--	--	.67	1.25	.98	1.61	.52	.53	.83	.87	.88	.59
Garson	5 km NE	1.02	.69	.69	.43	.80	1.27	.78	.75	.63	.61	1.09	.99	.95
Skead	26 km NE	1.12	1.20	1.20	1.01	.83	1.46	1.26	.92	.99	1.19	1.52	1.75	1.72
Kukagami Lake	42 km NE	1.60	1.28	1.28	1.23	1.65	1.10	1.38	.94	1.04	1.10	2.48	2.17	2.25
Grassy Lake	64 km NE	.60	1.75	1.75	.62	1.38	2.05	1.67	1.78	1.73	1.55	2.03	2.03	2.07
Lake Temagami	80 km NE	.98	.35	.35	.69	1.71	2.15	1.87	1.24	1.39	1.48	2.35	2.70	2.77
Callum	29 km E	1.13	1.32	1.32	.49	1.10	1.19	1.09	.96	1.34	1.32	1.15	1.65	1.46
Sturgeon Falls	77 km E	.17	1.05	1.05	.14	1.49	1.24	.80	.35	.30	.62	1.73	1.98	2.00
St. Charles	48 km SE	--	1.52	1.52	.78	1.43	1.17	1.56	1.54	1.69	1.81	1.78	2.07	2.07
Burwash	27 km S	1.15	1.33	1.33	.44	.92	1.22	1.71	.97	1.07	1.07	1.49	1.93	2.12
Tilton Lake	15 km SW				.79	1.80	1.26	1.18	1.23	.04	1.21	2.23	2.4	2.33
Lake Penage	37 km SW	.14	.14	1.29	.64	1.52	1.96	1.17	1.11	1.38	.71	2.35	2.60	2.80
Killarney	64 km SW	--	--	--	.31	1.12	1.08	.65	.52	1.18	1.15	1.40	1.35	1.17
Nairn Centre	48 km WSW	.24	.24	.48	1.42	1.92	1.56	1.01	.58	.85	1.05	1.90	1.92	1.77
Fairbanks Park	37 km W	--	--	--	1.40	1.35	1.61	1.87	1.21	1.49	1.99	1.27	1.65	1.85
Rayside Township	16 km NW	.97	.97	.67	.24	1.11	1.08	.54	1.00	.98	1.08	.63	.43	.55
Morgan Township	24 km NW	1.16	1.16	1.17	.39	.63	1.10	.63	.76	.72	.70	1.22	1.09	.96

Normal Concentration Guideline = 3.5% dry weight

* Control Location

** Soil Depth 0-10 cm for samples collected in 1970-1976.

*** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 51

Concentrations of Lead (ug/g) in Soil Samples Collected in the Sudbury Area 1973-1984***

Plot	Distance and Direction from Sudbury	YEAR**								
					1979			1984		
		1973	1975	1976	0-5 cm	5-10 cm	10-15 cm	0-5 cm	5-10 cm	10-15 cm
Blind River*	160 km W	14	22	16	8	6	6	20	9	7
Mattawa*	176 km E		12	12	6	5	5	8	5	5
Sudbury	0 km	25	28	15	40	10	7	36	10	8
Milnet	37 km N		27	26	--	--	--	24	18	16
Chiniguchi Lake	57 km NNE		21	22	10	5	5	8	3	2
Garson	5 km NE	8	18	18	16	6	7	13	5	4
Skead	26 km NE	46	26	25	29	7	7	54	12	16
Kukagami Lake	42 km NE	10	30	25	104	10	7	36	51	58
Grassy Lake	64 km NE	23	45	37	17	13	11	13	16	7
Lake Temagami	80 km NE	11	20	24	27	13	9	24	8	4
Callum	29 km E	13	34	12	10	5	5	27	6	4
Sturgeon Falls	77 km E	18	26	15	26	15	5	16	10	6
St. Charles	48 km SE	13	24	17	18	9	6	28	15	11
Burwash	27 km S	4	21	35	10	5	5	21	12	11
Tilton Lake	15 km SW	19	24	26	55	24	14	21	10	10
Lake Penage	37 km SW	19	67	35	58	5	5	19	10	17
Killarney	64 km SW	12	17	30	15	9	18	8	3	2
Nairn Centre	48 km WSW	20	36	40	15	7	7	34	20	19
Fairbanks Park	37 km W	10	20	31	17	5	8	40	13	10
Rayside Township	16 km NW	5	33	24	10	8	8	20	3	2
Morgan Township	24 km NW	8	16	28	5	6	5	13	5	2

Normal Concentration Guideline = 150 ug Pb/g Soil

* Control Location

** Soil Depth 0-10 cm for samples collected in 1973, 1975 and 1976.

*** Values reported are means of three monthly samples in 1973 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 52

Concentrations of Calcium (ug/g) in Soil Samples Collected in the Sudbury Area 1973-1984***

Plot	Distance and Direction from Sudbury	YEAR** 1973	1974	1975	1976	1979 0-5 cm	1979 5-10 cm	1979 10-15 cm	1984 0-5 cm	1984 5-10 cm	1984 10-15 cm
Blind River*	160 km W	269	1188	2470	2000	1500	5100	2500	2400	2417	2400
Mattawa*	176 km E	179	739	2570	1800	1800	2000	2000	1035	818	1472
Sudbury	0 km	159	660	1503	100	1800	1600	1900	757	963	977
Milnet	37 km N	135	282	1793	600	1900	1600	1800	1135	1038	1262
Chiniguchi Lake	57 km NNE	62	275	--	200	800	500	400	775	590	452
Garson	5 km NE	162	571	1200	500	1200	1300	1300	1583	1500	1383
Skead	26 km NE	30	497	336	400	1200	1500	1400	1613	1645	1370
Kukagami Lake	42 km NE	107	558	1237	800	1900	1000	1400	2650	2433	2367
Grassy Lake	64 km NE	323	1690	3977	500	4200	3600	3200	3333	3300	2950
Lake Temagami	80 km NE	173	924	1160	900	5600	4500	4000	3517	3767	3717
Callum	29 km E	311	1035	1830	1900	2000	1700	2200	1567	1683	1767
Sturgeon Falls	77 km E	1288	2110	542	1200	1800	1400	1400	2683	2983	2967
St. Charles	48 km SE	311	1743	1860	1600	3300	2400	2900	3317	3300	3400
Burwash	27 km S	188	288	2700	2800	2000	2200	2500	2065	1988	2020
Tilton Lake	15 km SW	42	116	1052	300	1500	1500	1400	1245	1195	1380
Lake Penage	37 km SW	645	2127	1700	5300	2700	1000	1000	3933	3350	3467
Killarney	64 km SW	334	222	693	800	1600	1300	1400	1315	1383	1333
Nairn Centre	48 km WSW	392	458	1870	1400	2500	2300	2700	2583	2617	2483
Fairbanks Park	37 km W	34	350	1191	600	1800	1800	1700	1803	1210	1140
Rayside Township	16 km NW	155	643	537	3000	2000	1900	2300	880	460	665
Morgan Township	24 km NW	643	3177	1830	3000	1800	2000	1700	2433	1817	1917

Normal Concentration Guideline = 30000 ug Ca/g Soil

* Control Location

** Soil Depth 0-10 cm for samples collected in 1973-1976.

*** Values reported are means of four monthly samples in 1973 and 1974 and two monthly values in triplicate in 1975, 1976, 1979 and 1984.

TABLE 53

Concentrations of Magnesium (ug/g) in Soil Samples Collected in the Sudbury Area 1973-1984***

Plot	Distance and Direction from Sudbury	YEAR** 1973	1974	1975	1976	1979 0-5 cm	1979 5-10 cm	1979 10-15 cm	1984 0-5 cm	1984 5-10 cm	1984 10-15 cm
Blind River*	160 km W	711	1850	1303	800	1000	2400	1400	2033	2233	2350
Mattawa*	176 km E	363	987	2097	1200	1200	1500	1800	730	593	1245
Sudbury	0 km	1973	1927	2210	1000	2000	2700	3700	983	1817	2183
Milnet	37 km N	1040	1425	2027	1100	2200	2100	2200	1333	1733	1917
Chiniguchi Lake	57 km NNE	700	1762	--	1100	500	400	900	922	887	396
Garson	5 km NE	1230	900	1450	1500	1500	1300	1300	2167	2083	2017
Skead	26 km NE	229	775	1006	1200	900	1300	1400	2467	2283	2467
Kukagami Lake	42 km NE	882	1483	847	1800	800	900	1200	1567	2317	1833
Grassy Lake	64 km NE	884	4500	4500	4000	4500	4800	3300	4050	4167	3750
Lake Temagami	80 km NE	1063	3187	1887	1400	2600	2400	3200	4583	5750	5967
Callum	29 km E	1120	2010	1177	2200	1500	2200	2400	1350	2183	2085
Sturgeon Falls	77 km E	1360	3270	600	1400	600	500	1000	3050	4017	4617
St. Charles	48 km SE	1120	2837	1937	2200	2200	2400	3000	4083	4850	5033
Burwash	27 km S	1255	1230	4487	4700	1600	2000	2400	2375	2777	2917
Tilton Lake	15 km SW	697	5650	1993	900	1400	1300	1800	2933	5717	3150
Lake Penage	37 km SW	2725	4760	7667	3400	1700	3100	2800	5783	6433	7033
Killarney	64 km SW	506	780	1237	1200	1200	1300	1300	2133	1950	1850
Nairn Centre	48 km WSW	1415	3090	1687	1800	1100	1600	2400	3200	3050	3283
Fairbanks Park	37 km W	1367	3425	2177	2800	--	--	--	1145	1520	2033
Rayside Township	16 km NW	1050	1303	727	700	1400	1600	2000	600	493	788
Morgan Township	24 km NW	1665	2487	2093	3800	2400	2300	2300	3100	2817	2733

Normal Concentration Guideline = 10000 ug Mg/g Soil

* Control Location

** Soil Depth 0-10 cm for samples collected in 1973-1976.

*** Values reported are means of three monthly samples in 1973 and 1974 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 54

Concentrations of Sulphur (%) in Soil Samples Collected in the Sudbury Area 1970-1984***

Plot	Distance and Direction from Sudbury	YEAR** 1970	1971	1972	1973	1974	1975	1976	1979 0-5 cm	1979 5-10 cm	1979 10-15 cm	1984 0-5 cm	1984 5-10 cm	1984 10-15 cm
Blind River*	160 km W	.02	.03	.04	.02	.03	.04	.03	.02	.02	.02	.03	.02	.02
Mattawa*	176 km E	.01	.04	.01	.02	.02	.02	.02	.01	.01	.01	.02	.01	.02
Sudbury	0 km	.02	.03	.06	.04	.04	.06	.03	.06	.03	.03	.05	.06	.06
Milnet	37 km N	.04	.03	.03	.02	.04	.04	.03	.02	.02	.02	.05	.03	.03
Chiniguchi Lake	57 km NNE	--	--	--	.04	.02	.04	.03	.01	.01	.01	.03	.02	.02
Garson	5 km NE	.03	.05	.03	.03	.05	.04	.03	.03	.03	.03	.03	.02	.02
Skead	26 km NE	.04	.10	.04	.08	.05	.10	.04	.03	.03	.03	.04	.03	.04
Kukagami Lake	42 km NE	.05	.06	.05	.02	.04	.05	.04	.04	.03	.03	.10	.07	.06
Grassy Lake	64 km NE	.04	.03	.03	.05	.04	.05	.07	.03	.03	.02	.03	.03	.03
Lake Temagami	80 km NE	.04	.02	.03	.02	.03	.03	.03	.05	.03	.03	.06	.04	.03
Callum	29 km E	.04	.05	.04	.03	.04	.05	.03	.02	.02	.02	.03	.02	.02
Sturgeon Falls	77 km E	.03	.05	.03	.04	.03	.05	.03	.02	.01	.01	.04	.03	.03
St. Charles	48 km SE	.04	.05	.03	.04	.03	.05	.03	.04	.03	.02	.04	.03	.03
Burwash	27 km S	.02	.05	.03	.03	.02	.03	.04	.02	.02	.02	.04	.03	.03
Tilton Lake	15 km SW	--	--	--	.05	.06	.05	.04	.05	.03	.02	.04	.05	.05
Lake Penage	37 km SW	.03	.09	.02	.03	.03	.05	.06	.06	.02	.02	.04	.04	.04
Killarney	64 km SW	--	--	.05	.03	.04	.04	.03	.03	.03	.03	.02	.02	.02
Nairn Centre	48 km WSW	.03	.09	.02	.04	.04	.04	.44	.02	.01	.02	.05	.03	.03
Fairbanks Park	37 km W	--	--	--	.04	.04	.04	.02	.03	.02	.02	.04	.03	.03
Rayside Township	16 km NW	.03	.03	.03	.04	.03	.04	.03	.03	.03	.03	.05	.02	.02
Morgan Township	24 km NW	.01	.03	.02	.02	.02	.03	.02	.02	.02	.01	.03	.01	.01

Normal Concentration Guideline = 0.1% S Soil

* Control Location

** Soil Depth 0-10 cm for samples collected in 1970-1976.

*** Values reported are means of four monthly samples in 1970, three monthly samples in 1971 through 1974 and two monthly samples in triplicate in 1975, 1976, 1979 and 1984.

TABLE 55

Summary of pH Values Measured in Soil Samples Collected in the Sudbury Area 1970 - 1979

Location	June/70	Aug/70	June/71	Aug/71	June/72	Aug/72	June/73	Aug/73	July/75**	Aug/75**	July/79**	Aug/79**
Skead	4.2	4.2	4.2	4.3	4.2	4.2	3.9	5.1	4.4	4.7	4.4	4.4
Milnet	3.9	4.3	4.2	4.2	4.6	5.3	4.9	5.1	4.9	5.2	4.8	4.8
Rayside	3.8	4.2	4.6	4.9	4.5	4.2	4.1	4.3	4.5	5.3	4.4	4.8
Grassy Lake	4.6	4.5	5.2	5.2	4.2	5.7	4.2	4.4	5.4	5.1	5.2	4.6
Kukagami	4.8	4.0	4.6	5.0	4.3	4.1	4.5	4.2	4.1	4.6	3.8	4.7
Callum	4.9	4.3	4.3	5.0	5.7	4.3	4.6	4.5	4.5	4.9	4.2	4.4
Garson	4.7	3.9	4.0	4.1	4.3	4.5	4.1	4.3	5.3	4.9	4.8	4.0
Burwash	5.2	5.2	4.6	4.3	5.2	5.2	4.6	4.8	5.2	4.9	4.8	4.1
Sudbury	4.0	4.0	4.3	4.9	4.7	4.0	4.3	4.4	5.2	4.7	4.3	4.0
Morgan	5.1	4.9	5.1	5.9	4.7	5.6	4.1	5.5	5.1	5.5	5.2	4.8
St. Charles	5.3	5.2	4.3	4.4	5.2	5.2	5.3	5.0	5.0	5.1	4.7	4.7
L. Penage	5.6	4.0	5.2	4.2	4.6	4.4	5.0	4.8	6.2	5.4	4.0	3.6
Sturgeon Falls	4.2	4.6	4.3	4.9	4.8	5.5	5.3	5.3	4.7	5.1	4.3	4.4
Nairn	3.9	4.6	4.6	6.3	5.2	5.4	4.9	4.5	4.8	5.4	4.0	4.4
Temagami	4.5	4.3	4.7	4.2	4.9	4.9	4.7	4.3	4.7	4.8	5.4	4.6
Killarney	—	—	—	—	4.7	3.0	4.6	4.5	5.0	4.9	4.6	4.6
Fairbanks Park	—	—	—	—	—	—	4.7	4.3	5.1	5.4	4.5	4.5
Tilton	—	—	—	—	—	—	4.5	4.5	4.4	4.7	4.3	3.8
Chiniguchi Lake	—	—	—	—	—	—	4.0	4.5	4.2	4.5	3.8	4.6
Blind River*	4.3	5.2	4.5	4.5	4.6	5.2	5.1	5.1	5.6	5.6	4.7	4.2
Mattawa*	4.6	5.0	4.7	4.5	5.6	5.3	5.3	4.8	5.1	4.7	4.8	4.8

* - Control Locations
** - Values reported are means of triplicate samples

TABLE 56

Concentrations of Copper (ug/g) in Moss from Mossbags Exposed in the Sudbury Area in 1976 and 1977

Site No.	1976 July	1976 Aug.	1976 Sept.	1976 Oct.	1977 June	1977 July	1977 Aug.	1977 Sept.
M1	38	17	47	18	17	59	230	120
M2	21	12	40	-	35	72	220	59
M3	174	33	291	121	55	120	200	150
M4	80	31	52	12	82	84	-	-
M5	64	32	-	49	38	7	-	-
M6	25	13	34	8	26	39	79	54
M7	50	14	33	31	34	64	175	77
M8	24	32	31	82	16	63	120	-
M9	203	31	292	115	126	133	300	360
M10	13	6	14	13	20	14	76	20
M11	71	14	52	41	56	69	126	190
M12	9	10	3	9	10	16	13	-
M13	12	10	11	6	25	26	48	32
M14	37	11	90	61	65	58	200	50
M15	284	-	193	325	510	123	176	95
M16	26	6	20	19	28	21	42	33
M17	6	6	5	5	14	13	17	14
M18	63	17	41	100	-	82	77	79
M19	72	4	5	10	7	8	17	10
M20					11	11	27	14
M21					25	31	48	35
M22					110	44	120	30
M24					-	35	55	-
M25					30	-	110	67
M26					99	86	280	98
M27					12	15	39	18
M28					13	25	39	21
M30					25	34	95	33
M31					28	34	40	-
M32					39	45	58	-
M33					29	29	64	30
M34					9	8	9	10
M35					17	20	33	67
M36					18	22	42	51
M37					-	380	1260	400
M38					104	133	-	-
M39					20	16	17	47
M40					20	14	30	57
M41					15	17	20	25
M42					23	18	35	26
M43					11	17	23	33
M44					23	26	19	24
M45					17	19	38	30
M46					36	62	78	-
M47					7	9	13	8
M48					10	9	12	8
M49					8	16	14	9
	Blank				7	-	8	9

Values underlined are in excess of 100 ug Cu/g

TABLE 57

Concentrations of Nickel (ug/g) in Moss from Mossbags Exposed in the Sudbury Area in 1976 and 1977

Site No.	1976 July	Aug.	Sept.	Oct.	1977 June	July	Aug.	Sept.
M1	24	13	29	16	16	48	70	95
M2	17	12	27	-	24	34	76	27
M3	69	19	240	59	52	68	72	70
M4	51	23	34	9	61	54	-	-
M5	49	26	-	36	39	6	-	-
M6	20	15	26	7	22	25	40	29
M7	46	16	22	20	22	38	52	48
M8	22	19	29	33	15	29	38	-
M9	79	12	240	59	93	75	94	100
M10	12	4	9	9	15	11	52	17
M11	59	8	45	31	56	39	69	93
M12	8	8	7	5	6	12	9	-
M13	13	4	12	6	25	19	27	16
M14	53	21	99	62	70	60	120	43
M15	980	-	320	760	640	78	140	85
M16	37	9	21	18	27	19	35	23
M17	7	9	6	4	12	11	12	8
M18	58	15	40	74	-	72	57	91
M19	85	9	6	2	7	6	10	8
M20					8	8	15	27
M21					26	23	30	-
M22					130	49	100	40
M24					-	26	35	-
M25					29	-	69	53
M26					124	130	148	98
M27					10	12	27	12
M28					16	20	38	16
M30					20	18	23	15
M31					25	20	34	-
M32					36	29	37	-
M33					23	20	7	18
M34					5	6	17	6
M35					9	9	27	37
M36					18	14	-	26
M37					-	240	300	90
M38					274	260	-	-
M39					19	13	12	25
M40					17	10	18	27
M41					11	11	15	18
M42					19	13	22	20
M43					8	7	15	20
M44					18	17	10	13
M45					12	11	19	19
M46					13	19	23	27
M47					5	5	9	5
M48					6	5	8	4
M49					6	8	11	6
Blank					5	-	6	5

Values underlined are in excess of 100 ug Ni/g

TABLE 58

Concentrations of Cobalt (ug/g) in Moss from Mossbags Exposed in the Sudbury Area in 1976 and 1977

Site No.	1976 July	1976 Aug.	1976 Sept.	1976 Oct.	1977 June	1977 July	1977 Aug.	1977 Sept.
M1	1	2	2	<1	2	2	4	4
M2	1	1	2	-	2	2	5	2
M3	3	1	10	2	2	1	6	4
M4	2	1	3	1	3	3	-	-
M5	2	1	-	2	2	1	-	-
M6	2	1	2	<1	2	2	2	2
M7	2	<1	2	<1	2	2	3	3
M8	2	<1	2	<1	2	2	2	-
M9	6	1	10	2	4	4	6	6
M10	2	<1	2	1	1	1	3	2
M11	1	<1	2	<1	3	2	4	3
M12	1	<1	1	<1	3	1	2	-
M13	3	<1	2	<1	2	1	1	2
M14	48	1	6	3	5	3	-	2
M15	2	-	15	30	32	7	13	5
M16	1	1	2	<1	2	2	3	3
M17	2	1	2	<1	2	1	2	2
M18	2	1	3	4	-	4	3	4
M19	4	<1	2	1	7	1	<1	2
M20					1	1	2	1
M21					1	2	2	2
M22					2	2	5	3
M24					-	1	2	-
M25					2	-	4	3
M26					5	5	14	5
M27					1	1	2	1
M28					2	1	3	1
M30					2	1	3	2
M31					3	1	2	-
M32					3	2	2	-
M33					2	1	2	2
M34					1	1	1	1
M35					1	1	2	2
M36					2	1	2	2
M37					-	11	19	4
M38					10	13	-	-
M39					2	2	2	1
M40					2	1	2	2
M41					2	1	1	2
M42					2	1	2	2
M43					2	1	1	2
M44					2	2	4	1
M45					2	1	1	3
M46					2	1	2	2
M47					2	1	2	1
M48					2	1	2	2
M49					2	1	2	1
Blank					2	-	2	1

Vaules underlined exceed 10 ug Co/g

TABLE 59

Concentrations of Iron (ug/g) in Moss from Mossbags Exposed in the Sudbury Area in 1976 and 1977

Site No.	1976 July	1976 Aug.	1976 Sept.	1976 Oct.	1977 June	1977 July	1977 Aug.	1977 Sept.
M1	720	570	730	482	880	980	1250	1120
M2	610	690	750	-	980	1030	1350	1030
M3	1100	660	1500	620	1000	1180	1270	980
M4	1000	600	680	500	1220	1100	-	-
M5	1300	720	-	640	1120	840	-	-
M6	770	630	680	468	1040	1010	1130	980
M7	730	550	620	436	880	1020	1150	195
M8	1180	610	540	530	880	1020	900	-
M9	530	560	1300	520	1020	1120	1270	1220
M10	1200	620	530	458	890	840	1520	940
M11	1200	660	690	487	1200	1120	1390	1040
M12	1000	670	560	467	960	920	990	-
M13	550	620	495	510	1090	990	1070	1060
M14	2200	750	1000	780	1600	1210	1600	1670
M15	4500	-	1600	2300	4800	1370	1600	1750
M16	1400	590	403	482	940	1020	1160	1070
M17	650	540	341	479	960	880	1040	960
M18	1000	710	374	740	-	2000	1330	1740
M19	720	530	560	530	770	860	870	830
M20					760	880	1350	1090
M21					1210	1120	1070	1090
M22					1700	1080	1400	1100
M24					-	1030	1060	-
M25					1090	-	1350	1430
M26					1840	1860	1800	2080
M27					910	920	930	950
M28					870	940	990	1060
M30					990	870	1160	980
M31					1200	1060	930	-
M32					1130	1010	1300	-
M33					990	940	1270	1030
M34					860	800	810	940
M35					990	850	1080	1000
M36					1030	800	1040	1030
M37					-	1500	1070	1190
M38					1070	1180	-	-
M39					1050	870	950	960
M40					980	860	900	1030
M41					920	930	840	960
M42					1060	430	950	1020
M43					900	480	810	1050
M44					920	900	800	960
M45					900	880	880	925
M46					1120	1040	1230	960
M47					790	880	980	890
M48					890	880	970	850
M49					800	930	990	940
Blank					890	-	890	920

Values underlined exceed 2,000 ug Fe/g

TABLE 60

Concentrations of Arsenic (ug/g) in Moss from Mossbags Exposed in the Sudbury Area in 1976 and 1977

Site No.	1976 July	1976 Aug.	1976 Sept.	1976 Oct.	1977 June	1977 July	1977 Aug.	1977 Sept.
M1	1.1	0.8	1.2	0.8	0.9	1.7	1.1	1.3
M2	1.2	0.9	0.9	-	1.1	1.0	1.1	0.9
M3	3.2	0.9	1.9	1.1	1.1	1.0	0.9	0.9
M4	2.6	1.9	2.2	0.8	2.4	1.5	-	-
M5	3.2	2.0	-	1.3	1.6	0.5	-	-
M6	1.3	1.2	1.0	0.8	0.8	0.9	1.0	0.7
M7	1.6	1.0	1.1	1.0	1.0	1.3	1.0	0.9
M8	1.4	1.2	1.6	1.1	1.0	1.0	1.4	-
M9	2.3	0.9	2.9	1.5	2.6	1.2	1.3	1.1
M10	1.3	0.6	0.8	0.9	0.7	0.6	1.6	0.7
M11	1.6	0.7	1.1	1.0	0.9	1.0	1.1	0.8
M12	1.0	0.6	0.7	0.7	0.5	0.8	0.7	-
M13	1.2	0.7	0.9	1.0	1.2	1.0	1.1	0.5
M14	2.9	1.6	5.4	1.5	2.5	2.6	6.5	1.6
M15	92.2	-	11.9	25.5	44.1	10.4	9.8	2.4
M16	2.5	1.0	1.2	1.5	1.6	1.2	2.0	0.7
M17	0.7	0.6	0.8	0.7	1.2	1.2	1.2	0.5
M18	2.3	1.2	1.6	2.3	-	4.8	1.6	0.9
M19	2.3	0.7	0.7	1.6	0.7	0.8	1.1	0.7
M20					0.8	0.8	1.5	0.7
M21					2.2	1.1	1.1	0.6
M22					8.6	3.5	3.2	0.7
M24					-	1.5	1.4	-
M25					1.7	-	5.9	1.5
M26					6.2	5.1	10.7	4.0
M27					1.0	1.2	1.5	0.5
M28					0.8	1.4	1.2	1.1
M30					1.2	1.0	0.7	-
M31					0.9	1.0	0.7	-
M32					1.2	0.8	0.7	-
M33					2.3	0.9	1.2	0.6
M34					0.6	0.6	0.6	0.5
M35					0.8	0.6	0.9	0.6
M36					0.8	0.5	0.9	0.7
M37					2.0	1.5	4.2	1.3
M38					2.4	2.1	-	-
M39					0.8	0.5	0.6	0.8
M40					1.1	0.5	0.9	0.8
M41					0.9	0.5	0.7	0.7
M42					1.1	0.9	0.8	0.7
M43					0.8	0.7	0.8	0.9
M44					1.1	0.9	0.7	0.9
M45					0.9	0.7	0.8	0.7
M46					1.0	1.0	1.6	0.5
M47					0.6	0.5	0.9	0.4
M48					0.7	0.5	0.8	0.4
M49					0.7	0.6	0.7	0.4
Blank					0.7	-	0.6	0.6

Values underlined exceed 3 ug As/g

TABLE 61

Concentrations of Lead (ug/g) in Moss from Mossbags
Exposed in the Sudbury Area in 1977

Site No.	1977 June	July	Aug.	Sept.
M1	36	42	64	59
M2	32	32	40	42
M3	32	40	56	52
M4	50	60	-	-
M5	46	30	-	-
M6	36	38	50	46
M7	34	44	74	46
M8	26	34	45	-
M9	34	30	48	55
M10	34	30	50	42
M11	30	30	46	45
M12	28	36	43	-
M13	40	38	42	42
M14	40	47	78	50
M15	118	40	50	100
M16	36	30	48	67
M17	32	28	43	36
M18	-	50	67	37
M19	13	25	38	38
M20	30	30	44	38
M21	40	38	47	46
M22	47	38	80	110
M24	-	44	42	-
M25	42	-	66	67
M26	44	44	70	50
M27	24	34	44	40
M28	36	42	48	59
M30	32	40	54	44
M31	50	52	47	-
M32	46	48	55	-
M33	28	46	62	40
M34	26	26	34	36
M35	24	34	47	50
M36	38	34	50	46
M37	-	50	87	60
M38	42	50	-	-
M39	34	32	38	40
M40	28	20	43	46
M41	32	30	40	42
M42	34	30	40	40
M43	32	28	44	43
M44	38	34	38	40
M45	52	62	83	63
M46	51	40	50	38
M47	28	24	36	36
M48	28	26	36	36
M49	34	38	44	40
Blank	31	-	33	34

Values underlined exceed 100 ug Pb/g

TABLE 62 *

Year	Amount Limed in Hectares	Amount Fertilized in Hectares	Amount Seeded in Hectares	Amount Site Improved in Hectares	Number of Trees Planted	Other Achievements As Specified
1978	114.8	114.8	114.8	206.3	-	30,000 pH and nutrient samples 365 kilograms of native seed collected 11,000 trees, shrubs and plants transplanted 122 compositing test plots
1979	478.6	466.6	420.2	295.9	4,250	420 hectares sampled for pH 425 kilograms of native seed collected 20,000 trees, shrubs and plants transplanted Monitoring and assessment begun.
1980	331.0	299.3	299.3	258.7	1,300	Land reclamation data assembled and computer coded. 2,000 pH samples taken 5 Year Land Reclamation Plan Developed
1981	208.0	173.4	173.4	9.8	4,600	5 Year Plan updated Monitoring and assessment records processed 29 research plots established
1982	362.4	342.4	305.2	199.2	-	Dismantled 2.4 km of abandoned trestle and improved tailings wildlife area
1983	1,084.0	934.6	935.4	-	228,080	Established 10 wildflower experimental test plots.
1984	57.7	188.4	215.9	7.5	149,350	Timber cruised 3,213 hectares Transplanted 400 trees Updated all mapping records Compiled second 5 year grassing plan.
1985	112.0	106.0	106.0	-	154,600	Native shrub seed sources identified. Land Reclamation Summary Report 1978-1984 published.
1986	24.0	30.0	30.0	-	80,300	5 year Tree Planting Plan developed. Monitoring survey of trees planted 1978-1985 completed. Forest management report prepared.
1987	59.5	64.7	64.7	-	263,530	Seeds of 15 species of trees or shrubs collected for diversity and future outplanting. Seed collection report prepared.
TOTALS	2,832.0	2,720.2	2,664.9	977.4	886,010	

* Table was produced and received from Bill Lautenbach, Sr. Planner, Regional Municipality of Sudbury